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THE RHYOLITE-DACITE-GRANODIORITE ASSOCIATION OF THE DANDENONG RANGES

By A. B. Edwards

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Abstract

The Dandenong Ranges, together with the hills to the north and south of them, comprise a rhyolite-dacite-granodiorite association typical of the Upper Devonian calc-alkaline igneous province of Central Victoria. It is about 30 miles east of Melbourne and has an area of about 130 square miles. The rock types recognized are toscanites, rhyolites, rhyodacites, biotite dacites and hypersthene dacites, intruded by granodiorites, granodiorite porphyrites, minor porphyrite intrusives, and a number of porphyrite dykes. Pyroclastics are associated with the lavas at a number of points.

The various groups of extrusive rocks are of magmatic origin, and underwent differentiation during the quiescent periods preceding their eruption, by a process of fractional crystallization and gravitational differentiation, influenced by the changes in chemical composition of the magma that resulted from assimilation of the argillaceous sediments forming the roof of the magma chamber.

The extrusion of the lavas led to or accompanied a collapse of the roof of the magma chamber—a cauldron subsidence of sorts—and this was followed by the intrusion of the granodiorites into the base of the lava flows.

Introduction

The igneous rocks described herein are part of the Upper Devonian calc-alkaline petrographic province of Central Victoria, and comprise both extrusive and intrusive rocks. They lie about 30 miles east of Melbourne and cover an area of about 130 square miles. Their combined outcrop has the form of an acute-angled isosceles triangle, the apex being to the north, midway between Lilydale and Coldstream, while the base extends more or less east-west from near Dandenong township to a point north of Pakenham township, just north of the Prince's Highway (Fig. 1). The rock types recognized in the area comprise toscanites, rhyolites, rhyodacites, hypersthene-dacite (verging on andesite), granodiorites, and a variety of minor dyke rocks, formed in that order. Pyroclastics have been found, intercalated with the extrusive rocks, at a number of points. The exposed granodiorite, which constitutes about 60% of the whole outcrop, lies chiefly to the south of an east-west line joining the Lysterfield Hills to Emerald township, but a considerable area near the Silvan Dam is underlain by granodiorite at shallow depth. Small residuals of Tertiary Older Volcanic basalts occur as outliers in the southern section of exposed granodiorite, the size of the outliers increasing to the south, and larger outcrops of basalts flank the Devonian extrusive rocks in the northern section.

The geological map accompanying the paper (Fig. 2) links together the maps of previous workers. The eastern boundary of the extrusive rocks between Evelyn and Emerald was mapped by Easton (1908) during a rapid survey of the Woori Yallock basin, and has been modified and somewhat diversified in the light of improved exposures. The east-west contact of the extrusive rocks with the granodiorite to the south was mapped in detail by Skeats (1910) and remains unchanged. The northern part of the area, between Coldstream and Mount Dandenong, was mapped in detail by Morris (1914), who first appreciated the diversity of the extrusive rock types present. Morris subsequently extended his mapping further south, but this work was not published, and is not available, so that this part of the area was re-mapped. Morris's boundaries in the northern part of the area were also re-mapped, and somewhat modified. Kitson (1902) made a rapid survey of the granodiorite boundaries in the vicinity of Berwick, and this area was mapped by Holmes, Leeper and Niccols (1940). More recently Hills (1941) demonstrated the presence of tuffs along the western scarp of the Dandenong Ranges, and re-interpreted the structure of this scarp.

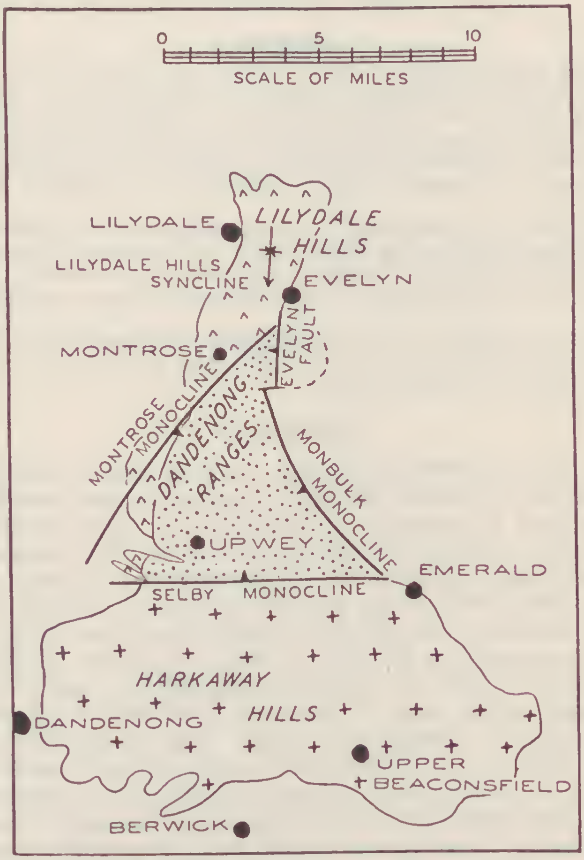

Fig. 1.—Sketch map showing the extent of the igneous rocks, and the three physiographic regions forming the Dandenongs Igneous Complex.

Physiography

The area consists of three naturally distinct regions, which will be referred to as the Lilydale Hills, the Dandenong Ranges, and the Harkaway Hills.

The Lilydale Hills

This name is introduced to describe the hills, composed of toscanites, rhyolites and rhyodacites, that stretch from midway between Lilydale and Coldstream, southwards to the northern slopes of Mount Dandenong (Fig. 1). Individual summits rise about 800 ft. above sea-level, and a number rise above 700 ft. The eastern margin of these hills is marked by Stringy Bark Creek, while their western edge is a low scarp rising above the broad flood plain of the lower part of Olinda Creek and the Croydon Lowlands. This scarp is masked somewhat in its middle course by the high-level residual of Tertiary olivine-basalt west of Cave Hill. In the north the hills end abruptly against the alluvial flats of Olinda Creek and its tributaries.

The streams are mostly small and intermittent, commonly with steep rocky valleys, and the drainage is dominated by Stringy Bark Creek, which flows northwards along the eastern margin of the hills, and Olinda Creek, which flows from south-east to north-west through the hills, but has its source and headwaters several miles to the south, on the eastern slopes of the Dandenong Ranges, and more or less on the line of Stringy Bark Creek. This upper part of Olinda Creek originated as the western lateral to the basalt flow extending southwards from Mount Evelyn township. In pre-basaltic times its water flowed along the eastern side of the Lilydale Hills, as the pre-basaltic continuation of Stringy Bark Creek, but the basalt, in filling this section of the old valley, diverted the water across the hills, so that it linked up with Olinda Creek (Edwards, 1939). The alluvium brought down by the steeply graded intermittent streams, and by the main streams, is deposited abruptly where they enter the flats. The depth of alluvium, even close to the edge of the igneous rocks, is considerable in places, as at the tile works quarry at the north-east end of Lilydale township, where on one side of the road is an outcrop of igneous rocks and on the other an exposure of alluvial sands and clays extending 30 ft. or more below the outcrop.

The Dandenong Ranges

The name Dandenong Ranges is here restricted to the high plateau-like mountain ridges that extend from Montrose and the east-west section of Olinda Creek, southwards to the Ferntree Gully-Gembrook railway line (Fig. 1). This region, consisting essentially of a great thickness of dacites and rhyodacites, with a little granodiorite and some indurated Palaeozoic sediments in the north, consists of a connected series of gently sloping or flat-topped ridges, whose crests lie between 1400 and 2000 ft. above sea-level. It is delimited by a series of scarps, and may be regarded as a tilted plateau-like block that has been extensively dissected.

The western margin is a continuous scarp, with only one major re-entrant, a double re-entrant, caused by the two branches of Dandenong Creek, where they debouch from the mountains at The Basin.

A somewhat lower scarp extends along the eastern side to near Emerald. This scarp is broken by a re-entrant where Olinda Creek has cut back towards Kalorama, and by a major re-entrant where Sassafras Creek has cut back into the ranges from The Patch almost to Sassafras.

The Sassafras and Dandenong Creek re-entrants, being almost opposite each other, give rise at Sassafras township to a saddle scarcely a hundred yards wide at 1550 ft. above sea-level, dividing the range into two main sections. The northern section is roughly triangular in shape, and is an asymmetrical ridge. The crest of the ridge is along the crest of the western scarp, rising from about 1600 ft. on Mount Dandenong North to 2078 ft. at Mount Dandenong, and about 2050 ft. at Barnes' Lookout, whence it trends south-east to Sassafras. In contrast to the steep descent to the west, and north-west, the surface slopes gently to the east, descending to about 1500 ft. at Mount Dandenong Church, and to about 1700 ft. at Olinda, where the slope steepens into the eastern scarp. The surface is not a uniform slope, but is dissected into spurs.

At Kalorama this northern section is reduced to a saddle about 50 yards wide, at 1500 ft., by the re-entrant of Olinda Creek, cutting off Mount Dandenong North from the main ridge.

The drainage pattern of the whole northern section is radial.

The southern section of the Dandenong Ranges is a south-east trending ridge, extending from One Tree Hill (1645 ft.) in the north-west to John's Hill (1375 ft.) in the south-east, and somewhat dissected by a series of south-flowing creeks. It is divided into two parts by the low saddle at Kallista (1175 ft.), caused by the headwaters of Monbulk Creek cutting northwards towards Sassafras Creek. The north-western part is the higher and broader of the two. Its highest point (1850 ft.) is the prominent hill immediately south-west of the Ferny Creek-Sherbrook crossroads (Memorial), whence it falls to 1550 ft. near Sherbrook Lodge. The south-eastern part is narrower and asymmetrical. It extends from east of Kallista to John's Hill, rising to heights of 1450 ft., and has a steep, slightly embayed scarp to the north-east. The southern slope is gentler, though still steep, and is dissected into a series of spurs by creeks (Ferny Creek and the branches of Hardy Creek) tributary to Monbulk Creek.

Menzies Creek is of interest in that, rising in a series of small south-flowing creeks, it turns south-east along the margin of the range proper, to its south-eastern corner, and then turns north to join the Woori Yallock Creek.

The Harkaway Hills

The name Harkaway Hills is used here for the apparently nameless area of hills of granodiorite extending from the line of Monbulk Creek and from the Selby to Cockatoo section of the railway line, southwards almost to the Prince's Highway, at a lower level than the Dandenong Range. Judged by the heights of the ridge tops, this area is a dissected plateau, the surface of which sloped to the south-west. Along the northern margin the heights of the granodiorite ridge and the hilltops rise progressively from about 600 ft. at Lysterfield to over 1000 ft. between Clematis and Emerald, and to 1150 ft. south of the railway line between Emerald and Cockatoo. Southwards from Cockatoo the levels fall steadily to 800 ft. at Upper Beaconsfield and 600 ft. near Pakenham. At Narre Warren North they are about 600 ft., and at Wilson's Hill and near Berwick, where the summits of the hills are basalt-capped, about 450 to 500 ft. Along the southern margin there is an abrupt descent equivalent to a scarp to the northern edge of the Koo-Wee-Rup Swamp, which is here 50 to 100 ft. above sea-level. In the northern part of these hills the streams trend SSW and SW in a definite pattern, related to the slope and the jointing of the granodiorite. Further south the influence of the southern scarp-like edge makes for south-flowing streams, particularly between Berwick and Pakenham.

The name Harkaway Hills is proposed to distinguish these hills from the pronounced ridge of hornfels rising to 790 ft., known as the Lysterfield Hills, on their north-western margin.

Nomenclature

I have deliberately adhered to the older terminology of Morris (1914) in order to preserve the awareness of sequence of extrusion necessary to the argument

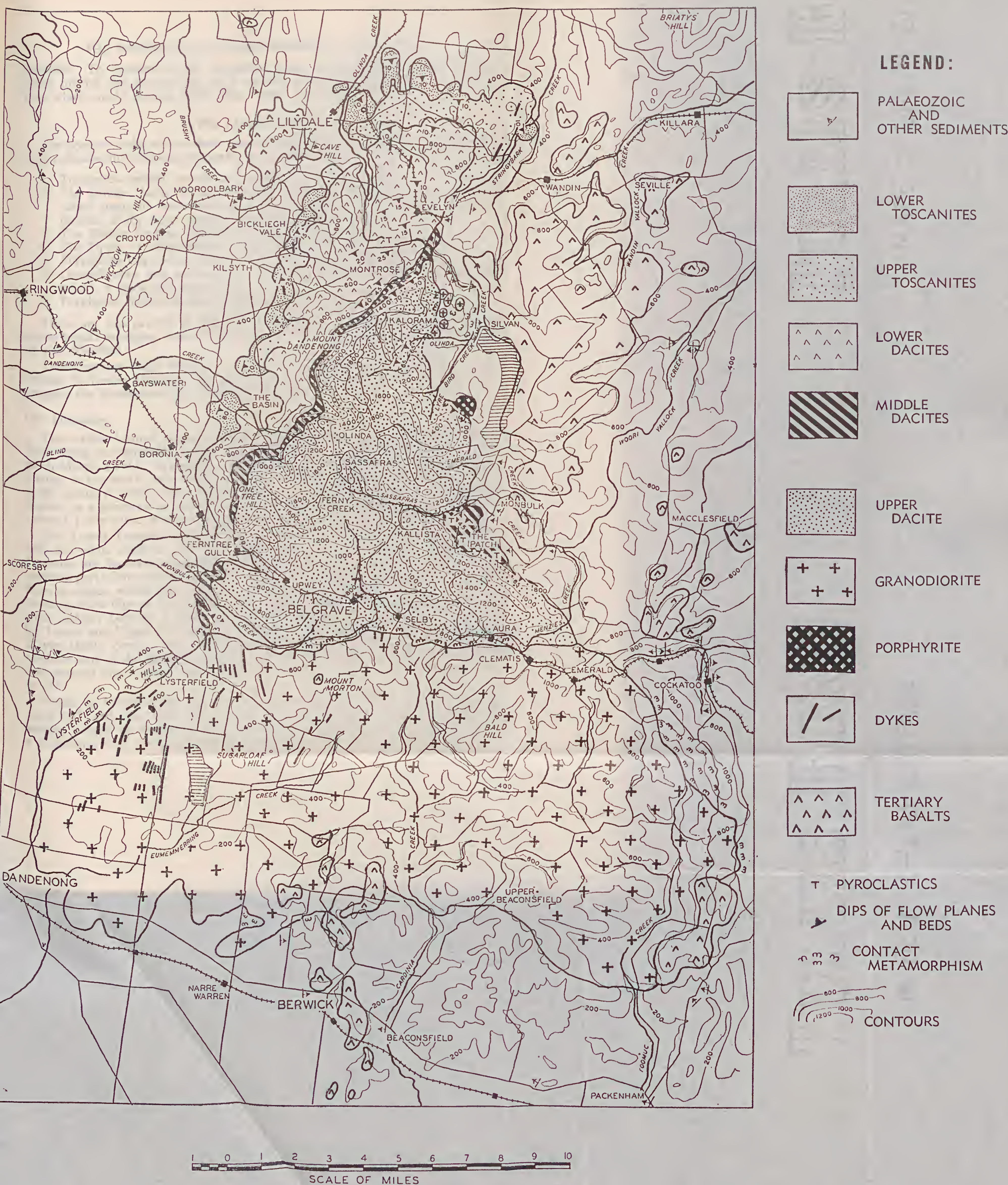

Fig. 2.—Geological map of the Dandenongs Igneous Complex.

presented. To conform to the Australian Code of Stratigraphic Nomenclature would involve the introduction of a number of locality names for the various lavas which would confuse rather than clarify the concepts presented.

The Igneous Rocks

The igneous rocks will be dealt with in their order of extrusion and intrusion. They comprise the following mappable units, beginning at the base of the series:

1. Toscanites—which include a Lower and an Upper series.
2. The Lower Dacite Group—comprising flows of rhyolite, rhyodacite and dacite, many of them fragmental, in that order of superposition, with the rhyolite at the base, together with intercalated pyroclastics.
3. The Middle Dacites—rhyodacites and related pyroclastics.
4. The Upper or Hypersthene Dacite—the major extrusion.
5. Porphyrite intrusions—minor intrusions (plugs and/or dykes).
6. Granodiorites and granodiorite porphyrites—a small batholith (100 sq. miles), a stock and some dykes.
7. Porphyrite dykes—a minor dyke swarm in the batholith.

There are also present in the area a number of flow residuals and dykes of olivine basalts belonging to the Tertiary Older Volcanics, but these, though mapped, are not described.

These various rocks overlie or intrude Lower Palaeozoic sediments of (?) Silurian to Lower Devonian age, that had been folded during the orogeny that preceded the development of the igneous rocks.

The Toscanites

The earliest-formed extrusive rocks of the complex are a series of toscanites. These rocks are chemically similar (Table 1), but they fall into two distinct groups, which Morris (1914) termed the Lower and Upper Toscanites. The two groups outcrop in concentric belts along the north-eastern, northern and western margin of the extrusive rocks, from a point about a mile north-east of Evelyn Railway Station, to a point as far south as Boronia. The outcrops have the form of an inverted J, the curve of the J being convex to the north (Fig. 2).

The Lower Toscanite extends further south than the Upper Toscanite, which does not occur south of Scoresby Shire quarries. The outcrops of the Lower Toscanite are, however, discontinuous, being of the nature of valley flows. In the northern part of the area the erosion of the original interfluves has left these valley flows as ridges, which slope down gently towards the south. The flow lines of the toscanite show dips of from 10° to 15°, directed more or less radially towards a point midway between Lilydale and Wandin Railway Station. The contacts of the Lower and Upper Toscanite, and of the Upper Toscanite with the overlying Lower Dacite Series, show similar radially disposed dips, indicating that the northern part of the igneous complex, the area comprising the Lilydale Hills, has been warped into a gently dipping syncline, with a southerly pitch of about 10° to 15°.

South of Montrose the dip of the Lower Toscanite flow planes steepens to about 70°, and this steep dip persists in all the toscanite outcrops along the western margin of the Dandenong Ranges. The steepening of the dip is due to a monoclinal warp trending across the extrusive rocks from the vicinity of Evelyn

TABLE 1
Analyses of Toscanites

	1	2	3	4	5	6
SiO_2 ..	68·19	69·98	68·57	67·74	70·30	69·93
Al_2O_3 ..	14·98	14·91	15·05	14·58	15·34	15·14
Fe_2O_3 ..	0·74	1·15	0·92	2·51	1·98	1·30
FeO ..	2·74	2·60	2·74	2·35	2·15	2·33
MgO ..	0·29	0·36	0·42	0·54	0·10	0·26
CaO ..	1·95	1·31	2·63	2·42	0·20	1·80
Na_2O ..	3·34	3·00	3·01	2·85	2·84	3·36
K_2O ..	3·64	4·26	3·71	5·24	3·46	3·55
H_2O+ ..	1·40	1·06	0·68	0·09	2·22	0·83
H_2O- ..	0·14	0·16	0·15	1·40	0·39	0·07
CO_2 ..	1·93	0·12	1·80	0·01	nil	nil
TiO_2 ..	0·20	0·79	0·20	0·26	0·25	0·25
P_2O_5 ..	0·05	0·09	0·08	0·08	—	0·03
MnO ..	0·08	0·09	0·08	0·08	—	0·05
Cl ..	tr.	0·02	nil	tr.	—	tr.
SO_3 ..	nil	0·03	tr.	nil	tr.	nil
BaO ..	0·27	—	0·30	—	—	0·30
	99·94	99·93	100·34	100·16	99·23	99·15

Explanation

1. Lower Toscanite, Black's Quarry, allot. 24, parish of Yering (*Proc. Roy. Soc. Vic.*, 24 (1914); 353).
2. Lower Toscanite, upper part, cutting on crest of old Healesville road, between allots. 1 and 24, parish of Yering. *Analyst*—G. C. Carlos.
3. Lower Toscanite, most westerly quarry, allot. 49, parish of Mooroolbark (Ringwood: 340.343). *Analyst*—A. B. Edwards.
4. Lower Toscanite, quarry on SW side of road from The Basin to Bayswater, allot. 71, parish of Scoresby (Ringwood: 330.326). *Analyst*—G. C. Carlos.
5. Upper Toscanite, quarry east of Colchester road, allot. 51, parish of Mooroolbark (Ringwood: 346.347) (*Ann. Rept. Sec. Mines Vic. for 1908*, p. 66).
6. Upper Toscanite, quarry 1 mile east of Mooroolbark, allot. 22C, parish of Mooroolbark (*Proc. Roy. Soc. Vic.*, 24 (1914); 353).

State School south-westwards towards Bayswater (Hills, 1941). As a result of the warping, the toscanite outcrops in the vicinity of the monocline approximate in form to the cross-section of the infilled valleys, which now stand in a nearly vertical position.

The Upper Toscanite, which was more of a sheet-like extrusion than the earlier flows, has a correspondingly more continuous outcrop than the Lower Toscanite.

Lower Toscanite. This rock is well exposed in Black's quarries, close to the railway line at the north-western extremity of the pronounced ridge running in that direction, midway between Lilydale and Coldstream, and in the roadside quarries on the adjacent ridge to the east. Other excellent exposures occur in the cuttings of the Lilydale-Warburton railway line, just north of Lilydale township; in the more westerly of the Scoresby Shire quarries on Liverpool Road, north of The Basin; and in the quarry on the south side of the Bayswater-Basin road. When fresh it is a dark greenish to bluish-grey rock, with occasional phenocrysts of felspar in a dense base. It weathers to various shades of buff and cream. Its distinctive and characteristic feature is a fine platy flow structure which causes it to break into plates from 5 to 10 mm. thick. This flow structure is most prominent in the lower parts of the flows, particularly when the rock is weathered, but may be overlooked in freshly broken, unweathered rock.

At Black's quarries, where the rock is exposed in faces 100 ft. high, the rock has a pronounced columnar structure. The columns have their long axes at right angles to the walls of the original valley, which trended NW-SE, and dip to the north-west, as a result of the synclinal warping of the district. The platy flow-lines lie at right angles to the long axes of the columns, so that they are parallel to the curvature of the valley floor. Occasionally they are folded into small drag-folds of several inches amplitude, presumably from movement of the lava as it became viscous. In some specimens there are two strongly marked series of parallel bandings, of identical appearance with the flow lines, inclined at an angle of 60° to one another. One slightly shears the other (the true flow planes), and they influence the jointing, so that there is a tendency for the rock to break into triangular fragments and blocks.

In the higher parts of these flows the parallelism of the flow structure is less perfect and grades into a sub-parallel arrangement of phenocrysts and dark streaks, which though irregular is still prominent. The change can best be observed during an ascent of the hill immediately east of the road from Lilydale to Coldstream, near the northern margin of the igneous rocks, starting from the quarries alongside the old road that crosses the shoulder of this hill, or by going south-eastwards along the ridge from Black's quarries. This upper phase is best exposed in the railway cutting of the Lilydale-Warburton railway line, north of Lilydale, where the railway line bends to the south-east, and passes under the wooden bridge leading to Black's quarries. The low elevation of the upper phase at this point (R.L. 350 ft.) compared with its higher elevation further north (450 ft.) is due to the southerly dip of the Lower Toscanite in this vicinity.

Morris (1914, p. 338) thought this change in the flow structure almost sufficient to warrant subdivision of the Lower Toscanite. He also suggested that a a third, still higher, phase existed, but this uppermost phase cannot be distinguished from the Upper Toscanites. Moreover, a change of slope always accompanies its outcrop, and the change in the rock is abrupt. It has been mapped, therefore, as Upper Toscanite, as a result of which the boundary of the Lower Toscanite and Upper Toscanite shown in Fig. 2 differs somewhat from that shown by Morris. With this change of interpretation, the faulted junction shown by Morris (the Lilydale Fault) becomes a normal junction corresponding to a south to south-easterly sloping contact between the two rocks, with outliers of Upper Toscanite on the higher ground west of the main junction.

Immediately south of Bickleigh Vale the marginal Lower Toscanite is highly fragmental, the included fragments consisting of altered Lower Devonian (Yeringian) sediments. The Palaeozoic sediments just to the west form hills that rise 50 to 100 ft. above the base of the toscanite.

In thin section the rocks from the lower parts of the flows are found to consist of sporadic squarish phenocrysts of felspar, from 0·5 to 1 mm. across, set in a cryptocrystalline groundmass of felspar, chloritized biotite and a little quartz. The phenocrysts are partially altered to sericite, but occasionally show lamellar twinning, with a maximum extinction angle of about 20°. They are optically positive, and so are andesines of composition about $Ab_{60}An_{40}$.

The felspar in the groundmass consists of lath-like microlites, with apparent parallel extinction, and more abundant more or less rectangular crystals of orthoclase up to 20 microns in diameter. The crystals show flow alignment to varying degree, so that the texture of the rock might be described as micro-trachytic. The plagioclose microlites might be oligoclase, but the very small amount of CaO (other than calcite) in the chemical analyses suggests that they approach albite in composition. It is possible, however, that part of the lime in the calcite that is commonly present in these rocks is derived from the original plagioclase. The biotite occurs as minute flakes, commonly completely altered to green chlorite. In some sections, however, the chloritization is only partial, and the biotite is pleochroic in greens and browns. The biotite is distinctly concentrated into parallel strings and drawn out lenses, which mark the closely spaced flow planes of the rock. The flakes of biotite in these flow planes are somewhat larger than those in the body of the rock, and small crystals of quartz, distinctly larger than those that occur throughout the groundmass, are associated with them. Iron ore occurs throughout the sections as uniformly distributed fine dust. In a number of sections the groundmass is spotted throughout with small areas of calcite.

Occasionally the rock appears in thin section to be more basic, approaching in composition to an andesite rather than a toscanite. This variation is found in the roadside quarry on the south side of the Bayswater-Basin road, about ¼ mile on the Bayswater side of The Basin school at (Ringwood: 325.320).* The groundmass felspar is composed predominantly of minute laths of plagioclase, with an extinction angle of 15 degrees, accompanied by rectangular or lath-like, untwinned crystals of orthoclase. The laths show flow arrangement, small areas of the groundmass showing uniform extinction. The texture of the rock is pilotaxitic to micro-trachytic. Associated with the chloritized biotite are numerous small grains of sphene, and a little calcite. Some sections are spotted throughout with calcite. The iron ore in this rock is rather coarser than in the more normal toscanite, and is chiefly magnetite, occurring as idiomorphic crystals, some approaching the size of microphenocrysts. A comparable rock occurs in allotment 25, parish of Yering, and in allotment 4, parish of Gruyere. A chemical analysis of the Bayswater road rock (Table 1, Analysis 4) shows, however, that it is not significantly different chemically from the other Lower Toscanites.

The rocks from the upper phase of the Lower Toscanites are vesicular in some outcrops. Phenocrysts of felspar are somewhat more abundant, and have their long axes parallel to the flow structure. The flow planes are marked by broader, more irregular concentrations of biotite. The biotite occurs in coarser flakes and is generally accompanied by relatively coarse crystals of calcite, and of quartz, forming irregular sub-parallel lenses through the rock. The other distinctive feature of these rocks is that there appears to be more quartz in the groundmass. It forms more or less micro-granophyric intergrowths with the groundmass felspars, so that under crossed nicols the groundmass appears to be patchy.

Upper Toscanite. The Upper Toscanites, when fresh, are blue-black aphanitic rocks, with occasional phenocrysts of felspar up to 2 mm. long, and generally rectangular in shape. They weather to various shades of grey, buff and near-white, when they resemble indurated sediments. They are readily distinguished from the Lower Toscanites by their lack of flow structure, and their blocky jointing, which causes them to break into more or less cubic pieces. When weathered, the joint planes are commonly outlined by films of limonite. Fragmental Upper Toscanite is prominently developed in the north-eastern part of the area (Ringwood: 440.440), where innumerable fragments of Silurian sediments, showing various degrees of metamorphism, are caught up in a matrix of what appears to be Upper Toscanite. Somewhat similar agglomerates occur in the Upper Toscanite forming

*Ringwood Sheet (1935), Military Survey of Australia.

the two conical hills just east of Grey's Road (Ringwood: 436.440), and can be seen to overlie the Lower Toscanite on the northern flank of the more northerly of these two hills. Fragmental Upper Toscanite overlying Lower Toscanite also occurs just south of Bickleigh Vale, and here fragments of Lower Toscanite showing typical flow structure have been caught up in the Upper Toscanite in conjunction with sedimentary fragments. In thin section the Upper Toscanites closely resemble the Lower Toscanites. They are even finer-grained, however, and show no flow structures. Also, they contain much less biotite in their groundmass, which is sometimes impregnated with granules of calcite. Chemical analyses show no significant difference of composition.

The Lower Dacites

Overlying the toscanites is a series of flows and pyroclastics which Morris (1914) termed the "Lower Dacites". These rocks are characterized by a prevailing grey, greenish-grey or green colour, and by the presence of abundant phenocrysts of quartz, and occasional large pink garnets. In addition they almost invariably contain numerous angular rock fragments, up to an inch across, or even larger. The fragments consist of hornfels, toscanite and dacite. They are generally sufficiently enclosed in porphyritic dacite whose groundmass shows flow structure to leave no doubt that the rocks are flows.

More than one flow, and probably a large number of small flows, is present, but the general similarity of the rocks and the inadequate exposures make it impossible to define the limits of the individual flows, or the extent of the intercalated pyroclastics. Thin beds of tuff, a few feet thick, are exposed in a road cutting on the south side of Yorke Road near its junction with Inverness Road, along the south bank of Olinda Creek (Ringwood: 393.387). These beds dip at 25° S. Occasional poorly exposed occurrences of tuff have been observed along the road leading from this point to Evelyn, and on the adjacent hillsides.

The dacites on either side of this E-W section of Olinda Creek are highly fragmental, and in the right-angle bend of Olinda Creek at the eastern end of this section flow rocks give place to coarse agglomerate with fragments up to 12 inches across, some of them rounded, and most of them hornfels. Morris (1914) interpreted this occurrence as marking the site of a centre of eruption, and he described the dacites outcropping on the steep slopes leading from this E-W section of Olinda Creek up to Mount Dandenong as "entirely fragmental", ranging from "coarse agglomerate to dun-coloured lapilli containing no visible minerals". The lapilli he reported as always higher than the agglomerate, and probably marking the final stage of the Lower Dacite extrusions.

The section through these rocks exposed subsequently in the road cuttings of the Mountain Highway, leading from Montrose to Kalorama, do not support Morris's interpretation of these rocks as "entirely fragmental", but reveal them to be essentially fragmental lavas such as are found elsewhere in the formation, with occasional intercalated agglomerate beds. Thus Hills (1941) reports an agglomerate bed dipping at 30° SE exposed in two small quarries about 200 yards above Long View House (Ringwood: 385.370), and lying between Lower Dacites showing flow planes that dip in conformity with the agglomerate bed.

Examination of the disconnected outcrops on the hill slopes below the road, between it and Olinda Creek, confirms that the greater volume of these rocks are fragmental dacite flows rather than agglomerate.

Extent. The Lower Dacites form the greater part of the Lilydale Hills, extending southwards from the Lilydale-Warburton road to the lower slopes of Mount Dandenong. Flow planes are commonly present and show a prevailing dip to the south and to the south-east (in the western part of the Lilydale Hills). North of Olinda Creek the flow planes dip at 10° to 15°, but south of the Creek (Yorke Road) the dip increases, until along the Mountain Road it is as high as 55°.

The Lower Dacites extend along the western flank of the Dandenong Ranges to the railway line just west of Upper Ferntree Gully, and a small outcrop interpreted as Lower Dacite occurs at the western end of the ridge crossing the Lysterfield road on the north bank of Monbulk Creek. As far south as the railway line these rocks appear to dip at angles of 60° to 90° to the south-east or east, the easterly dips developing at the southern end. In the Glenfern Quarries, close to Upper Ferntree Gully Station, Hills (1941) reports several thin, impersistent beds of tuff containing fragmental plant remains that strike N 20 W, and dip at 80° W, whereas elsewhere in the quarry he found the flow planes and bedding planes dipping at 70° to 80° easterly. He also records the occurrence of massive beds of pyritized tuffs on the eastern side of the quarry, establishing the presence of several lava flows at this locality. In the vicinity of The Basin, also, more than one flow can be recognized, but the outcrops are too discontinuous for the individual flows to be mapped.

Rhyolites. Despite the number of flows involved, a progressive variation in composition is evident, extending from the base of formation to the top. The rocks at the base are rhyolites and fragmental rhyolites (Table 2, Analysis 7), consisting of numerous embayed phenocrysts of quartz, and many fewer phenocrysts of orthoclase, together with an occasional corroded pink garnet, set in a glassy to cryptocrystalline groundmass showing flow structure. Rock fragments are common, and consist chiefly of hornfels and toscanites.

The rhyolites occur all along the northern edge of the Lower Dacite formation, and along its north-western edge nearly to Montrose. Rocks near the Salvation Army Boys' Home near The Basin also appear to be rhyolites. The junction of the rhyolites with the Upper Toscanite is commonly marked by a distinct change in the slope of the hillside; and the gently south-dipping joint planes in the rhyolite reveal the attitude of its base.

There is no sharply defined top to the rhyolites, but rather a gradation into the overlying quartz dacite, 200 ft. to 300 ft. above the base, as indicated on the geological map (Fig. 2).

There must have been other rhyolite areas, because fragments of rhyolite are not uncommon in the Lower Dacite lavas higher in the formation, and the pyroclastics south of The Patch on the eastern side of the Dandenong Ranges contain rhyolite fragments.

Rhyodacites. As the formation is followed upwards, at about 200 ft. to 300 ft. above the base, the rhyolite grades into a grey rhyodacite closely comparable with the grey "quartz dacite" of the Maroondah Dam area (Edwards, 1932a). The groundmass becomes increasingly crystalline, though still only microcrystalline; the quartz phenocrysts are joined by phenocrysts of felspar, both orthoclase and oligoclase, which come to outnumber the quartz; and most thin sections and hand specimens contain phenocrysts of pink garnet, about 2 mm. across. The garnet is an almandine, like that in other Victorian dacites (Edwards, 1936).

TABLE 2

Analyses of Rocks of the Lower Dacite Series

	7	8	9	10
SiO_2	73·85	68·73	64·06	64·75
Al_2O_3	14·45	13·16	17·86	15·47
Fe_2O_3	0·61	1·17	1·78	1·08
FeO	1·20	2·74	2·90	4·75
MgO	0·83	1·22	1·49	2·36
CaO	1·40	3·03	3·01	3·94
Na_2O	2·09	2·30	2·44	3·01
K_2O	5·19	2·59	3·01	2·10
H_2O+105°C	0·21	1·86	1·63	1·11
H_2O−105°C	0·10	0·09	0·20	0·41
CO_2	nil	1·50	0·18	nil
TiO_2	0·28	0·50	0·68	0·80
P_2O_5	tr.	0·17	0·16	0·26
MnO	0·10	0·09	tr.	0·05
SO_3	—	nil	nil	0·03
FeS_2	—	0·18	0·11	—
Cl	—	tr.	nil	nil
BaO	—	0·20	—	—
Totals	100·31	99·47	99·60	100·12

Explanation

7. Rhyolite, base of the Lower Dacite Series, ½ mile NE of the railway bridge over the Lilydale-Healesville road, and the Lilydale township (Ringwood: 388.434). *Analyst*—A. B. Edwards.
8. Quartz-dacite, railway cutting between Lilydale and Evelyn, allot. 30C, parish of Mooroolbark. (*Proc. Roy. Soc. Vic.*, 24 (1914); 353.) *Analyst*—F. F. Field.
9. Quartz-dacite, allot. 65, parish of Mooroolbark, cutting in road along NE boundary of allotment. *Analyst*—F. F. Field.
10. Felspathic Lower Dacite, The Basin, allot. 53M, parish of Scoresby (Ringwood: 328.307). *Analyst*—G. C. Carlos.

Two analyses of these rhyodacites (Table 2, Analyses 8 and 9) show the considerable change in composition from the rhyolite to the rhyodacite but indicate that the rhyodacites are relatively consistent in composition. The differences in SiO_2 and Al_2O_3 shown by Analyses 8 and 9 could be due to experimental error, as indicated in a later section. Analysis 8, with the higher SiO_2 figure, is more likely to be the correct composition of the rock.

This phase of the Lower Dacites is about 300 ft. to 400 ft. thick and outcrops over most of the southern half of the Lilydale Hills and along the western side of the ranges as far south as The Basin.

Green felspathic phase. Still higher in the Lower Dacite formation the felspar phenocrysts become more prominent, largely by a more abundant development of plagioclase, which occurs as glomeroporphyritic clots, and dominates the orthoclase, and particularly the quartz. Ferromagnesian minerals appear as phenocrysts but have been converted to a bright green chlorite, as have any ferromagnesian minerals in the groundmass. As a result the rock has a general green colour, studded with white felspar prisms. Some yellow epidote is associated with the chlorite, together with a little granular sphene—a breakdown product from former biotite. In addition minute grains and films of pyrite and pyrrhotite occur in places.

This green felspathic dacite is distinctly richer in CaO, FeO and MgO than the grey rhyodacites, as well as somewhat less siliceous, as may be seen from Table 2, Analysis 10. It extends all along the north-western and western side of the Dandenong Ranges, and also occurs in the outcrops adjacent to Monbulk Creek, at the southern limit of the dacites.

Morris (1914, p. 345) appears to have regarded this rock as part of his "Middle Dacite Series", in that it overlies the more fragmental dacites which he termed the "Dandenong Agglomerates" and accepted as the top of the Lower Dacites. In view of the purely local occurrence of this agglomerate, and the fact that the "dun-coloured lapilli" beds appear to occur above the green felspathic dacite, it seems better to include it with the Lower Dacites. The variation diagrams (Figs. 3 and 4) support this interpretation, in that the green felspathic dacite appears somewhat more basic than the Middle Dacites proper, and fits well to curves of the other Lower Dacite analyses.

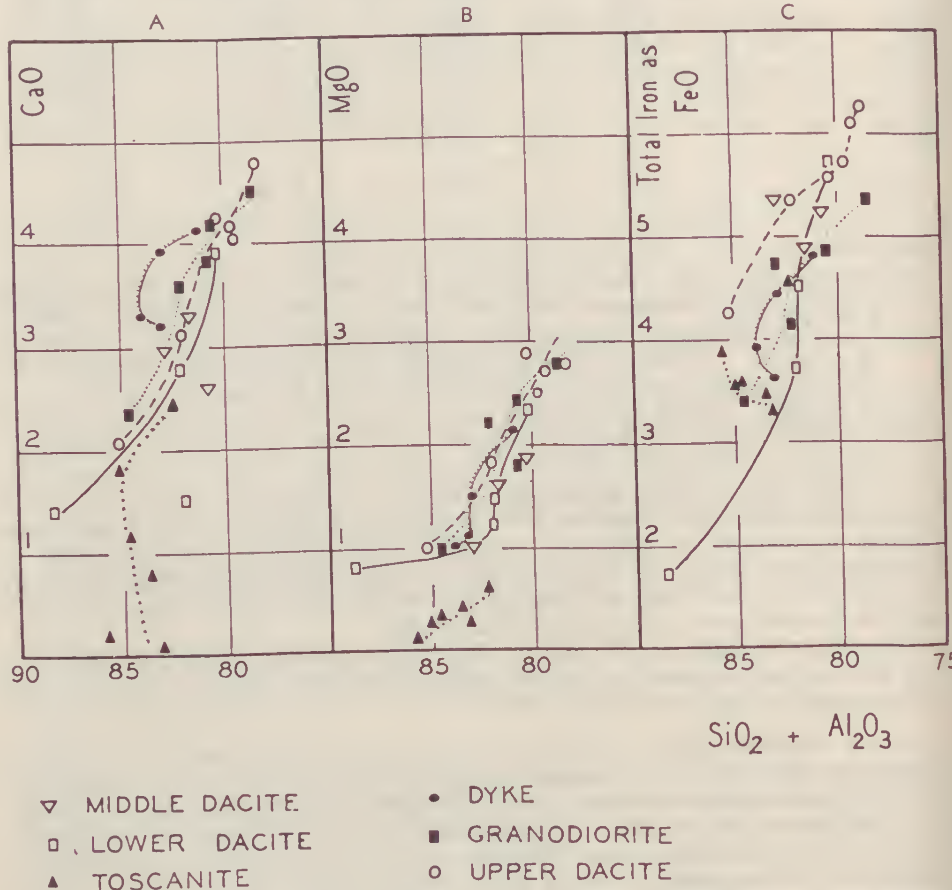

FIG. 3.—A. Variation of CaO in relation to ($SiO_2 + Al_2O_3$).
B. Variation of MgO in relation to ($SiO_2 + Al_2O_3$).
C. Variation of total iron as FeO in relation to ($SiO_2 + Al_2O_3$).

Moreover, the tuff beds at the top of this dacite separate it from a distinctive flow or flows, darker in colour, and with more numerous and coarser phenocrysts of quartz, and a distinctive groundmass. This contact is mappable for considerable distances along the north-western and western sides of the ranges.

This green felspathic phase is about 200 ft. to 300 ft. thick, increasing in thickness towards Ferntree Gully.

The Middle Dacites

This group of lavas is precisely demarcated from the overlying Upper Dacite by the distinctive black chilled base of the Upper Dacite, which is devoid of quartz phenocrysts, whereas the Middle Dacite beneath it, though dark, contains abundant quartz phenocrysts, and resembles the rhyodacites of the Black Spur (Edwards, 1932a), which occur in a similar stratigraphic position, with hypersthene dacite above, and rhyolites and grey quartz dacite (rhyodacite) below. In places the distinction between the two is rendered somewhat difficult because the Middle Dacite has a dark chilled top, in which the quartz phenocrysts are not obvious in the hand specimen. Along the western side of the Dandenong Ranges, however, the contact of the two is the more evident from the occurrence of thin beds of tuff at the contact. As exposed in the cuttings of the Mountain Highway from Montrose to Kalorama, these tuffs, and the flow planes in the adjacent rocks, dip at 70° to 75° SE.

It has been possible to trace this tuff bed southwards along the western scarp of the ranges as far as the One-in-Twenty Road from The Basin to Sassafras. It is exposed in an old quarry on the road to "Doongala", near the head of Dandenong Creek, where it is pyritized, and in the roadside on the road from the Salvation Army Home to Olinda (Mount Dandenong Hotel). Between the Mountain Highway and these exposures there is no prominent outcrop, but blocks of tuff, more or less *in situ*, occur at short intervals, and outcrops of Middle Dacite are found below them, but not above. Similar blocks of tuff have been observed as far south as The Basin-Sassafras road.

Morris (1914) placed the base of the Middle Dacites as directly above the highly fragmental phase of the Lower Dacite which he termed the "Dandenong Agglomerates", and differentiated it as containing no fragmental material.

In addition he recognized two variations in the Middle Dacites:

(i) a lower grey rock showing numerous phenocrysts of felspar, quartz and biotite, together with garnets, in a glassy groundmass showing flow lines; and

(ii) an upper dark rock, with fewer but larger phenocrysts of quartz, felspar and biotite in a groundmass of quartz, felspar and biotite "shimmering" with minute biotite flakes (a very apt description of its appearance under crossed nicols), to which it owes its dark colour.

The cuttings of the Mountain Highway, between Montrose and Kalorama, built subsequently to Morris's study, provide an almost continuous section through the Lower Dacites, Middle Dacites and the Upper Dacite on the northern flank of Mount Dandenong, and permit a more precise definition of boundaries.

As noted by Hills (1941), the rock described by Morris as the "upper type" of Middle Dacite—the dark rock with large phenocrysts of quartz and felspar, and a groundmass "shimmering" with minute flakes of biotite—is sharply bounded by the Upper Dacite (hypersthene dacite) above, and by a band of fossiliferous tuff below. Beneath this tuff bed are grey and greenish-grey porphyritic lavas, notably fragmental in places, which correspond in detail to Morris's Lower Dacites. As noted in the section dealing with the Lower Dacites, the exposures in these cuttings reveal that the "Dandenong Agglomerates" are of only local extent, and their top is ill-defined, so that they do not form a mappable horizon. In contrast, the dark rock with large phenocrysts of quartz and felspar, accepted by Hills as the Middle Dacite, can be traced as a belt about 800 ft. to 1000 ft. thick along the western side of the Dandenong Ranges to a point west of One Tree Hill, and a fairly sharp junction with the underlying green felspathic Lower Dacites can be mapped over this distance of about five miles. It is possibly a single flow, and is relatively free from rock fragments. A small outcrop of the same dark rock occurs on the south bank of Monbulk Creek, at the western edge of the dacites; and an identical rock, except that it contains rock fragments, occurs east of The Patch, on the eastern margin of the Dandenong Ranges, where there are no associated grey or green rocks.

For these reasons Hills's (1941) definition of the Middle Dacite is adopted here, and Morris's (1914) "lower type" of Middle Dacite is included with the Lower Dacites. Incidentally, this appears to conform with Morris's labelling of his own thin sections.

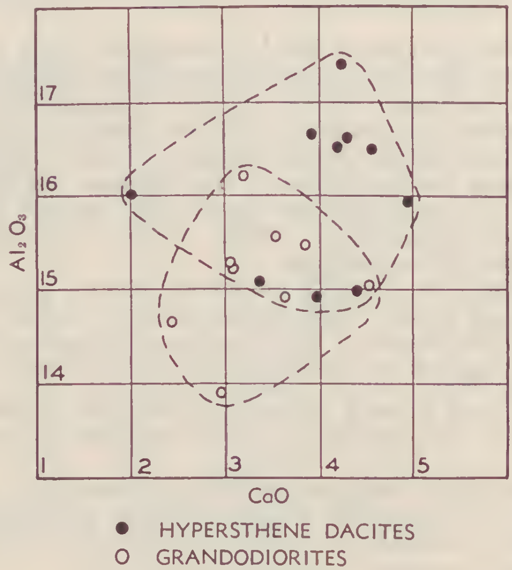

Fig. 4.—Variation of CaO in relation to Al_2O_3 for hypersthene dacites and granodiorites.

Chemically, the felspathic phase of the Lower Dacites, immediately below the Middle Dacites, as here defined, is a somewhat more basic rock than such Middle Dacites as have been analysed (Figs. 3 and 4), although two of the three Middle Dacite analyses fit well to the curves for the Lower Dacite analyses. These three analyses are shown in Table 3.

TABLE 3

Analyses of Rocks of the Middle Dacite Series

	11	12	13
SiO_2	65·83	65·26	67·45
Al_2O_3	14·89	16·38	15·54
Fe_2O_3	0·73	1·36	1·90
FeO	4·63	3·70	3·62
MgO	1·88	1·67	0·92
CaO	3·13	3·45	2·99
Na_2O	2·12	2·63	2·18
K_2O	2·32	3·92	3·63
$H_2O+105°C$	2·41	0·29	0·65
$H_2O-105°C$	0·17	0·04	0·06
CO_2	0·47	0·06	nil
TiO_2	0·89	0·57	0·75
P_2O_5	0·16	0·30	0·28
MnO	0·10	0·09	0·04
SO_3	nil	0·04	nil
FeS_2	0·10	—	—
Cl	tr.	—	nil
BaO	0·13	—	—
NiO	0·01	—	—
Totals	99·93	99·70	100·01

Explanation

11. Middle Dacite, NE flank of Mount Dandenong (*Proc. Roy. Soc. Vic.*, 24 (1914); 353).
12. Middle Dacite, 1 in 20 road (Mountain Highway), between The Basin and Sassafras (Ringwood: 427.284). *Analyst*—G. C. Carlos.
13. Middle Dacite, from Camm's Jam Factory site, east of the The Patch (SW of Monbulk) (Ringwood: 342.305). *Analyst*—G. C. Carlos.

The belt of rocks interpreted as Middle Dacites in the vicinity of Camm's Jam Factory, east of The Patch, are fragmental, and undoubtedly extrusive. Poor outcrops, mainly floaters, along the northern margin of this occurrence suggest that it is underlain by Lower Palaeozoic sediments, and that its base dips southwestwards at 40° to 45°. The shape and limited extent of this rock indicates that it represents a flow that has infilled a valley and subsequently been tilted.

The major embayment in the eastern scarp of the Dandenong Ranges, at The Patch, appears to mark the occurrence of a considerable thickness of pyroclastics lying between the base of the Upper Dacite (hypersthene dacite) and this outcrop of Middle Dacite at Camm's Jam Factory. Exposures are poor, but the road cuttings, particularly on the road to the Jam Factory, expose occasional beds of severely weathered rocks striking N-S or W of N, and dipping at 40° to 50° W or SW. Some of these beds resemble mudstone, others contain igneous fragments with coarse plates of biotite, kaolinized felspar and quartz phenocrysts. Floaters of similar weathered rock occur in the cuttings of the road leading across to Monbulk from the Kallista-Emerald road at co-ordinate point Ringwood 427.272. Here the pyroclastics appear to underlie the chilled base of the Upper Dacite and to overlap on to the Middle Dacite flow, but the exposures are too poor to yield dips.

A much better exposure of pyroclastics occurs further to the SE along the Kallista-Emerald road, where it junctions with the Tea-Tree Creek road (Ringwood 443.250). A small cutting exposes tuff and agglomerate containing fragments of rhyolite and toscanite up to 6 in. across, in an igneous-looking matrix. The pyroclastics can be traced SE along the Emerald road in the drainage gutters, and in a creek bed west of the road, for several hundred feet, nearly to the spring in which this creek rises. The beds dip at about 50° to 65° SW, under the hillwash from the overlying Upper Dacite, and appear to rest directly on the Palaeozoic sediments.

On the geological map these pyroclastics, which have a maximum thickness of about 2000 ft., are shown as Middle Dacite. The Middle Dacite flow outcrops along the eastern edge of this area for about 1000 yards, and is up to 1000 ft. thick.

Upper Dacite or Hypersthene Dacite

The uppermost flow of the series, termed by Morris (1914) the Upper Dacite, appears to be a single extrusion, like the Middle Dacite. It is upwards of 1000 ft. thick and caps the whole of the Dandenong Ranges proper, having an outcrop area of about 35 sq. miles, equivalent to a volume of not less than seven cubic miles and could be as much as 5000 ft. thick (Fig. 7), which would give a volume of 35 cubic miles. It is a hypersthene dacite, identical in composition and stratigraphic position with the hypersthene dacite of the Black Spur-Warburton district (Edwards, 1932a, 1932b), and closely similar to the hypersthene dacite of Macedon (Skeats and Summers, 1912).

Its junction with the underlying Middle Dacite is well defined along the western scarp of the ranges, in places by a zone of severely weathered rock, and everywhere by its well marked chilled base.

The basal rock is dark black to blue-black, consisting of phenocrysts about 0·5 mm. across of zoned plagioclase, with labradorite cores, and hypersthene in a dense glassy base. Ascending through the extrusion, the glassy base becomes increasingly crystalline and the proportion of phenocrysts increases. The rock becomes correspondingly lighter in colour and coarser grained. The change is accompanied by the development of biotite in flakes up to 1 or 1·5 mm. across, in increasing amounts, at the expense of hypersthene, which has reacted with the orthoclase in the groundmass, the reaction progressing more effectively with slow cooling until in the higher parts of the flow the rock is a light blue-grey coloured hypersthene-biotite dacite. Occasional quartz phenocrysts are present, and rare augite phenocrysts. The dark colour of the chilled base persists for about 200 ft. above the base. Compared with the other rocks of the complex, it is relatively free from rock fragments, though in fact it contains quite a proportion of hornfels fragments, particularly in its basal parts.

The change in appearance is accompanied by a distinct change in chemical composition. As may be seen from Table 4, the dark rock of the chilled base is 67 to 69 per cent SiO_2, whereas the lighter coloured rock high in the extrusion is only about 63 per cent SiO_2, and is correspondingly richer in FeO, MgO and CaO, and also in TiO_2. Moreover, as may be seen from Fig. 4, this rock, for a given SiO_2 content, is the most iron-rich of the complex.

Richards (1909) separated the hypersthene, biotite and ilmenite of the rock and analysed them, and the hypersthene dacite from which they were derived (Table 5). If the compositions of the hypersthene, biotite, ilmenite and plagioclase phenocrysts are subtracted from the analysis of the rock, according to their modal proportions, using the data provided by Richards (Tables 5, 6 and 7), the residue, recalculated to 100 per cent, indicates that the groundmass of the rock has a composition about

TABLE 4

Analyses of Upper or Hypersthene Dacites

	14	15	16	17	18	19	20
SiO_2 ..	69·26	66·91	63·27	63·45	64·50	62·73	72·7
Al_2O_3 ..	16·34	15·17	16·50	14·99	14·94	17·41	12·8
Fe_2O_3 ..	1·14	1·96	0·68	1·21	1·15	0·45	0·2
Fe_2O ..	3·33	3·59	5·10	5·18	5·09	5·17	2·6
MgO ..	1·08	1·84	2·48	2·81	2·78	2·94	1·4
CaO ..	2·07	3·11	4·18	4·40	4·01	4·25	3·0
Na_2O ..	3·30	2·58	2·36	3·18	3·29	2·03	1·8
K_2O ..	2·00	3·39	2·68	2·88	2·46	3·39	3·7
H_2O+ ..	0·26	0·33	0·52	0·41	0·24	0·66 }	0·5
H_2O- ..	0·01	0·08	0·09	0·08	0·29	0·16 }	
CO_2 ..	nil	nil	nil	nil	nil	nil	—
TiO_2 ..	0·81	0·74	1·30	1·12	0·99	0·93	1·2
P_2O_5 ..	0·29	0·28	0·15	0·15	0·26	0·23	—
MnO ..	0·08	0·05	0·03	0·02	0·03	tr.	0·1
Cl ..	nil	nil	nil	nil	nil	tr.	0·1
SO_3 ..	nil	0·02	nil	nil	0·01	nil	—
FeS_2 ..	nil	—	0·16	—	—	0·30	—
Totals ..	99·97	100·05	99·50	99·88	100·04	100·56	100·00

Explanation

14. Chilled base of the hypersthene dacite, a few feet above the contact, road cutting, main Montrose-Kalorama road, northern scarp of Mount Dandenong North (Ringwood: 400.374). *Analyst*—G. C. Carlos.
15. Chilled base of the hypersthene dacite, about 20 ft. above the contact, road cutting on Mountain Highway ("1 in 20" Road), from The Basin to Sassafras (Ringwood: 343.304). *Analyst*—G. C. Carlos.
16. Hypersthene dacite, near Upwey Railway Station. *Analyst*—H. C. Richards (*Proc. Roy. Soc. Vic.*, 21 (1910); 533).
17. Biotite-hypersthene dacite, close to Sassafras-Ferny Creek road, one mile south of Sassafras township (Ringwood: 468.294). *Analyst*—A. B. Edwards.
18. Biotite-hypersthene dacite, near War Memorial, Ferny Creek-Sherbrook Forest roads junction (Ringwood 469.293). *Analyst*—G. C. Carlos.
19. Hypersthene dacite, road cutting on main Montrose-Kalorama road, allot. 925A, parish of Mooroolbark, 15 chains north of Kalorama. *Analyst*—F. F. Field.
20. Calculated composition of the groundmass of the hypersthene dacite at Upwey (Analysis No. 16), computed from data given by Richards (*Proc. Roy. Soc. Vic.*, 21 (1910), 533, and quoted in Tables 5, 6, and 7).

equivalent to that of a rhyolite (Table 4, Analysis 20). Since the phenocrysts in the more acid chilled base are similar to those in the upper more basic portion of the flow, but less numerous, it is evident that the change in composition from bottom to top is related chiefly to the proportion of phenocrysts present at any one level in the flow. Since the upper parts of the flow represent the deeper levels of the magma in the magma chamber, this may be taken as evidence that the plagioclase and hypersthene phenocrysts were sinking in the magma at the time of extrusion, and that a more prolonged sinking of such phenocrysts could have given rise to rhyolitic lava. It suggests that a body of magma of the composition of the hypersthene dacite, and of the order of 5000 to 10,000 ft. thick, could differentiate to form a considerable volume of rhyolite and related rock types.

TABLE 5

Composition of Minerals in the Upper Dacite at Upwey
(from Richards, 1909)

	21	22	23	24
SiO_2 ..	63·27	39·86	50·42	—
Al_2O_3 ..	16·50	11·13	4·06	—
Fe_2O_3 ..	0·68	1·39	2·10	nil
FeO ..	5·10	18·10	23·54	31·92
MgO ..	2·48	9·88	13·04	0·80
CaO ..	4·18	tr.	1·30	—
Na_2O ..	2·36	0·35	tr.	—
K_2O ..	2·68	6·73	0·69	—
H_2O+ ..	0·52	3·20	0·06	—
H_2O- ..	0·09	0·43	0·10	—
CO_2 ..	nil	nil	nil	—
TiO_2 ..	1·30	7·95	3·51	67·28
P_2O_5 ..	0·15	tr.	0·92	—
S	0·16	—	—	—
MnO ..	0·03	0·58	0·24	tr.
Li_2O ..	tr.	tr.	—	—
Totals ..	99·50	99·60	99·98	100·00
Sp. Gr. ..	2·76	3·16	3·36	4·86

Explanation

21. Hypersthene-biotite dacite.
22. Biotite.
23. Hypersthene.
24. Ilmenite.

Analyst—H. C. Richards.

TABLE 6

Modal Analysis of Upper Dacite from Upwey
(from Richards, 1909)

	% vol.	% wt.
Phenocrysts		
Plagioclase (Ab_1An_1) ..	25·50	24·13
Hypersthene	10·27	12·17
Biotite	9·83	10·96
Ilmenite	0·62	1·08
Quartz	1·31	1·22
Groundmass		
Felspar	24·31	22·95
Quartz	21·74	20·34
Biotite	6·42	7·15

On the eastern side of the ranges the Upper Dacite overlies Palaeozoic sediments and pyroclastics related to the Middle Dacites, and is intruded by a body of quartz porphyrite and by granodiorite; along its southern margin it overlies intrusive granodiorite. Where it has been intruded, it is locally rendered schistose, the hypersthene being altered to biotite which has oriented itself normal to the intrusive contact.

TABLE 7

Composition of Groundmass of Upper Dacite

(from data given by Richards, 1909)

	Quartz	Felspar			Biotite		
		Or.	Ab.	An.			
SiO_2 ..	20·34	5·28	5·00	3·23	2·90	36·75	72·7
Al_2O_3 ..	—	1·51	1·42	2·75	0·79	6·47	12·8
Fe_2O_3 ..	—	—	—	—	0·10	0·10	0·2
FeO ..	—	—	—	—	1·32	1·32	2·6
MgO ..	—	—	—	—	0·72	0·72	1·4
CaO ..	—	—	—	1·52	—	1·52	3·0
Na_2O ..	—	—	0·86	—	0·02	0·88	1·8
K_2O ..	—	1·38	—	—	0·49	1·87	3·7
H_2O ..	—	—	—	—	0·26	0·26	0·5
TiO_2 ..	—	—	—	—	0·60	0·60	1·2
MnO ..	—	—	—	—	0·04	0·04	0·1
						50·53	100·0

Granodiorites

Two areas of granodiorite occur within the complex. For convenience of reference they are named the Lysterfield Granodiorite and the Silvan Granodiorite.

Lysterfield Granodiorite. The Lysterfield Granodiorite is a small batholith. It outcrops south of the line of Monbulk Creek and Menzies Creek, over an oval area about fourteen miles long (E-W) by seven miles wide (N-S). On the north, it is bounded by Upper Dacite for a distance of about seven miles, and on the east, west and south it is bounded by Lower Devonian (and Silurian) sediments, and by alluvium (Fig. 2).

The contact metamorphic effects of the granodiorite are prominent. The Upper Dacite has been rendered schistose along the whole length of the mutual contact (Skeats, 1910), the hypersthene being converted to biotite by reaction with the groundmass of the dacite, which has been recrystallized. Locally a strongly foliated biotite gneiss has resulted.

The effect on the invaded sediments varies somewhat, from conversion to dense purplish-black hornfels to little apparent alteration. A major development of hornfels is responsible for the Lysterfield Hills, the prominent narrow ridge of hills, 700 to 790 ft. high, forming the NW margin of the granodiorite outcrop. This hornfels zone extends for about two miles along the contact, and is from a quarter to a half mile wide; it has been quarried extensively for road metal. The hornfels shows no apparent extension SW of these hills, where the contact is masked by the alluvium of Dandenong Creek, but hornfels marks the contact near the Lysterfield-Ferntree Gully road, about 1 mile to the NE. The contact is then masked for a mile and a half by the alluvium of Monbulk Creek. When next seen the dacite has taken the place of the sediments.

A second major development of hornfels occurs on the north-eastern margin of the granodiorite area, forming a ridge, 1000 to 1100 ft. high, that trends south-easterly from the narrow gauge railway line for a distance of about three miles along contact. This zone is about a quarter of a mile wide. The northward extension of the granodiorite under cover is indicated by the occurrence of hornfels east of Menzies Creek at a point 465.252.

Along the southern margin the contact is commonly masked by alluvium, but some hornfels is found about midway between Narre Warren and Harkaway. The absence of hornfels from considerable stretches of the western and southern margins may be more apparent than real, since hornfelsed sediments on weathering resume their normal sedimentary appearance and relative softness (Edwards and Baker, 1945).

The petrological features of the Lysterfield Granodiorite have been described briefly by Skeats (1910) and by Baker (1942). In places, as at Mount Morton, it is essentially a biotite granodiorite, but over much of its extent it contains a little hornblende. In places, however, the hornblende becomes a significant component, as at Caversham Hill, about two miles east of Upper Beaconsfield, where a micrometric analysis shows the following proportions:

	%
Quartz	23·6
Orthoclase	17·4
Plagioclase	39·0
Biotite	15·4
Hornblende	4·6

The plagioclase, as noted by Skeats, generally exceeds the orthoclase in the ratio of about 2 : 1, and occurs as strongly zoned and idiomorphic crystals, 1 to 2 mm. across. It ranges in composition from labradorite in the core zones to oligoclase at the margins, and in general appearance resembles the plagioclase phenocrysts in the earlier hypersthene dacites, and in the later porphyrite dykes. The orthoclase and quartz are in about equal proportions, the orthoclase tending to show perthitic intergrowths of albite. The accessory minerals, as noted by Baker (1942), comprise actinolite, apatite, chlorite, epidote, ilmenite, orthite, sphene, tourmaline and zircon.

There seems to be a slight sympathetic variation in plagioclase and hornblende content, and these variations in composition are reflected in the three chemical analyses available, from the northern, western and south-eastern sections of the outcrop (Table 8, Analyses 27, 28, 29). The rock richest in hornblende has the highest FeO, MgO, CaO and TiO_2 content, and the lowest SiO_2 content of the three. Baker (1942) records variations in index numbers (proportion of heavy minerals, essentially biotite and hornblende) from different parts of the outcrop as follows: Narre Warren 13·5, Selby 15·5, Monbulk Creek 17·3, and Upper Beaconsfield (Caversham Hill) 19·5.

The granodiorite is much contaminated with xenoliths of sedimentary origin, in varying stages of assimilation or granitization, but has been completely deroofed, except perhaps at its northern margin. In the north-east, at Emerald, it rises to 1000 ft. (R.L.) and a ridge, whose highest parts are at 1000 ft. to 1050 ft. above sea-level, runs for about three miles south-east from Emerald to the head of Bourke's Creek. The high country extends along the northern contact, where the granodiorite surface is at about 800 ft., but southwards there is a gentle falling off in the heights of ridges and other high points, chiefly towards the south-west. Some heights of 800 ft. are attained along the eastern boundary.

The southern margin of the granodiorite area is marked by a rapid descent to the relatively low-lying Siluro-Devonian sediments and the Tertiary sediments and alluvium, indicating that the granodiorite mass has relatively steep sides, and had

Table 8

Analyses of Granodiorites

	25	26	27	28	29
SiO_2 ..	70·12	69·14	67·27	65·12	63.61
Al_2O_3 ..	14·66	13·94	14·96	15·52	15·09
Fe_2O_3 ..	1·53	2·24	1·10	0·74	0.93
FeO ..	1·96	2·71	3·13	4·21	4·56
MgO ..	0·99	1·17	2·22	2·45	2·82
CaO ..	2·34	2·97	3·63	3·86	4·52
Na_2O ..	2·25	3·60	2·92	3·76	4·06
K_2O ..	3·60	2·91	3·22	2·60	2·66
H_2O+ ..	1·22	0·67	0·78	0·81	1·01
H_2O- ..	0·37	0·15	0·10	0·06	0·13
CO_2	nil	tr.	nil	0·02	nil
TiO_2	0·52	0·36	0·59	0·69	0·90
P_2O_5 ..	0·22	0·12	tr.	0·11	0·18
MnO ..	nil	0·01	tr.	0·06	tr.
Cl	tr.	tr.	tr.	tr.	tr
SO_3	tr.	tr.	tr.	tr.	nil
FeS_2	0·10	—	—	—	—
BaO ..	—	—	nil	—	—
Totals ..	99·88	99·99	99·92	100·01	100·47

Explanation

25. Biotite-granodiorite, or adamellite, allot. 920, parish of Mooroolbark, flank of Mount Dandenong. *Analyst*—F. F. Field.
26. Biotite-granodiorite, spur north-east of Kalorama, close to contact with hypersthene dacite, allot. 920, parish of Mooroolbark (Ringwood: 413.367). *Analyst*—G. C. Carlos.
27. Biotite-hornblende-granodiorite, one mile south of Belgrave township. *Analyst*—M. Evans.
28. Biotite-hornblende-granodiorite, east of Lysterfield Hills, parish of Narre Warren, east of Police Paddock (Ringwood: 290.198). *Analyst*—G. C. Carlos.
29. Hornblende - biotite - granodiorite, from Mr. Hume's property, Cavendish Heights, Tumuc Valley, four miles north of Packenham township, four miles north. *Analyst*—F. F. Field.

a flattish surface, with probably small cupola-like protuberances, like Sugarloaf Hill, which rises abruptly for 150 ft. above the level of the ridge on which it occurs.

Silvan Granodiorite. The more northerly Silvan granodiorite, by contrast, scarcely outcrops. It underlies about a square mile of country extending from the northern end of the Silvan Dam westwards to the main saddle east of the Mountain Highway, north-east of Kalorama. This area is approximately that bounded by co-ordinate points 410.350 - 410.373 - 425.373 - 430.350, Ringwood Sheet (1935), Military Survey of Australia.

The cupola form of the granodiorite mass is demonstrated by the occurrence of hornfels and unaltered Siluro-Devonian (Lower Devonian) sediments in the bed of Olinda Creek (700 ft. R.L.) and at the summit of the hill to the west (1200 ft. R.L.), together with several small outcrops of granodiorite at the creek level, and on the flanks and near the summit of the hill. The largest of these outcrops is at 415.368 on the north-eastern slope.

The granodiorite was intruded subsequent to the formation of the Evelyn Fault, because the Upper Dacite along this fault has been metamorphosed by the granodiorite, in the immediate vicinity of their contact (412.367). Close to the granodiorite the Upper Dacite shows a weak schistosity, and a lightening in colour, combined with an increased amount of visible biotite. Thin sections show that the hypersthene has developed strong reaction rims of fine flakes of biotite against the groundmass, or has been made over more or less completely to decussate aggregates of biotite flakes. The groundmass has begun to recrystallize, so that under crossed nicols it has a "spotty" texture; the recrystallization has proceeded sufficiently to produce equigranular grains of orthoclase about 0.10 mm. across, studded through the original microcrystalline grains of quartz.

The base of this only partially unroofed cupola broadens just below creek level, in view of the considerable extent of hornfels exposed in the bed of Olinda Creek, and in test pits in the vicinity.

The granodiorite, where it outcrops, contains numerous xenoliths, and varies somewhat in appearance and composition. Morris (1914, p. 350) refers to the outcrops as dykes of granodiorite porphyry, consisting of numerous phenocrysts of plagioclase, with fewer phenocrysts of quartz and orthoclase, and clusters of biotite flakes in a groundmass that is essentially quartz and orthoclase. An analysis of one such rock from the north-east flank of the cupola (415.368) (Table 8, Analysis 25) shows the rock to be distinctly more acid than the Lysterfield granodiorite; in fact it is better described as granite or adamellite porphyry.

Exposures near the summit, and on the eastern and south-eastern flanks of the hill, consist however of a uniformly grained rock, with the individual crystals about 2 mm. across, of normal granitic appearance. Thin sections reveal them to be biotite granodiorite or adamellite, with zoned plagioclase crystals, like the southern granodiorite. A chemical analysis of a specimen taken from close to the hypersthene dacite contact (412.367) (Table 8, Analysis 26) is distinctly richer in SiO_2 than the Lysterfield granodiorite, and contains less MgO and CaO, but is not as potassic as the analysed specimen from the north-eastern flank (415.368).

Granodiorite porphyrite dykes. Morris (1914) mapped a large dyke of granodiorite porphyrite (the Wandin Dyke), which is 40 to 50 ft. wide and has intruded the Upper Toscanite to the north-west of Wandin, where it outcrops at intervals over a distance of about one and a half miles. It has a granitic appearance, and consists of large idiomorphic phenocrysts of zoned plagioclase and plates of biotite, together with smaller irregular grains of orthoclase, in a micrographic groundmass of quartz and orthoclase. It appears to be closely related to the Silvan granodiorite, particularly to its porphyritic phases.

Several isolated dykes of granodiorite porphyrite have been found by Gill (1942) invading the Palaeozoic sediments about two miles east of the toscanites and of the Wandin Dyke, in the vicinity of Wandin and Seville.

It is inferred from the occurrence of these dykes that the Silvan granodiorite has a considerable extension north and north-east of its outcrops, at relatively shallow depths.

Porphyrite Intrusions

Midway along the western fence of the Silvan Dam reservoir, in the central E-W section of the fence (Ringwood: 420.325), is an outcrop of quartz porphyrite, about 500 yards across. In the hand specimen the rock bears a resemblance to the Middle Dacites, but thin sections show phenocrysts of quartz, plagioclase and ragged biotite in a coarsely microcrystalline groundmass of quartz and blocky orthoclase. There is a little fine-grained biotite in the groundmass, but it is not the "shimmering" biotite of the Middle Dacite, and the texture of the groundmass points to a more slowly cooled rock.

On its western side, where the quartz porphyrite is in contact with the chilled base of the Upper Dacite, the Upper Dacite has been rendered somewhat schistose for 10 to 20 ft. from the contact, and its hypersthene phenocrysts have been converted to clusters of biotite flakes, by reaction with orthoclase in its groundmass, as at its contacts with the granodiorites. It is evident, therefore, that the porphyrite is an intrusive plug, younger than the Upper Dacite.

A similar quartz porphyrite has been recorded by Summers (1929) near the Silvan Dam site, where testing pits exposed an intrusive contact between the porphyrite and the Palaeozoic sediments.

A further small intrusion of porphyrite occurs in the Middle Dacite, just below its junction with the Upper Dacite on the spur immediately west of the Evelyn Fault (i.e. immediately west of the eastern edge of the dacites) at a point given by co-ordinates Ringwood: 405.382. The exposure is mainly in the form of floaters, with a few massive blocks apparently *in situ*. The rock in the centre of the occurrence, which is about 100 yards wide by several hundred yards long (E-W), is dense black and studded with white to greenish-white felspar prisms, up to 3 mm. long, and a few smaller quartz phenocrysts, and bears a close resemblance to the porphyrite intrusions invading the hypersthene dacite in the Warburton area (Edwards, 1932b). Thin sections reveal the felspar phenocrysts as zoned plagioclase, with labradorite cores, and the quartz phenocrysts as rounded and embayed. The groundmass has the same blocky texture as that in the intrusive porphyrite along the Silvan Dam fence line. Specimens from the poorly defined margin of the porphyrite suggest that it has chilled margins above and below.

A chemical analysis of this rock is given in Table 9, Analysis 32. It is not significantly different in composition from the dyke rocks intruding the Harkaway granodiorite near Lysterfield, being intermediate between the most acid and the least acid of the dykes, and it fits to variation curves drawn for these analyses (Figs. 3 and 5).

There is little evidence as to the age of these porphyrites relative to the granodiorites. Morris's collection of thin sections include three labelled as from the south (sic) side of Lyre Bird Gully, two of them more specifically "in the angle between Lyre Bird Gully and Olinda Creek". These are presumably from the occurrence reported by Summers (1929), but not located by me, so that I presume it has been buried by the earth works of the Dam. One section is of a porphyrite identical with the porphyrite on the fence line; the other two are of a similar rock, richer in biotite, in which the biotite flakes lie parallel to each other giving the rock a coarse foliation. They are described in Morris's handwriting as "gneissic upper toscanite", and could have been metamorphosed by the granodiorite along with the adjacent sediments.

Lysterfield Dyke Swarm

The granodiorite porphyrite dykes described by Morris (1914, p. 350) from the area underlain by the Silvan granodiorite have a similar groundmass of blocky orthoclase—"often in square or rhombic sections, with diagonal extinction".

Close to its north-west margin, at Lysterfield, and near the Lysterfield Hills, the Lysterfield granodiorite has been invaded by a small swarm of dykes. These dykes were first noted by Sutherland (1903). Upwards of sixty dykes have been mapped, with a total thickness of about 300 ft. Most of them are only 2 to 3 ft. wide, and cannot be traced for more than 100 yards along their strike, but an occasional dyke is up to 20 ft. wide, and as much as a mile long. At one point

TABLE 9

Analyses of Dyke Rocks

	30	31	32	33
SiO_2	69·49	68·80	67·66	65·84
Al_2O_3	14·72	14·32	15·36	15·26
Fe_2O_3	1·34	1·19	0·74	1·77
FeO	2·71	2·57	3·84	3·26
MgO	1·02	1·11	1·52	2·12
CaO	3·33	3·98	3·24	4·17
Na_2O	2·98	2·51	3·02	2·34
K_2O	2·44	3·80	2·24	3·67
H_2O+	0·77	0·75	1·42	0·75
H_2O-	0·14	0·07	0·04	0·11
CO_2	0·06	nil	tr.	nil
TiO_2	0·65	0·57	0·62	0·48
P_2O_5	0·27	0·26	0·24	0·27
MnO	0·07	0·07	0·06	0·09
Cl	0·01	tr.	0·01	tr.
SO_3	0·01	tr.	0·01	tr.
Totals	100·01	100·00	100·02	100·13

Explanation

30. Light hornblende porphyrite dyke (No. 48), allot. 59, parish of Narre Warren (Ringwood: 300.206).
31. Dense dark porphyrite dyke (No. 46), north-east corner allot. 60, parish of Narre Warran (Ringwood: 307.202).
32. Felspar-porphyrite plug or dyke, intruded into Middle Dacite, north-east flank of Mount Dandenong, west of Evelyn Fault (Ringwood: 405.383).
33. Felspar-hornblende porphyrite dyke (No. 27), intersection of allots. 70, 70A and Monbulk P.R., parish of Narre Warren (Ringwood: 346.223).

Analyst—G. C. Carlos.

(Ringwood: 306.210) a plug about 20 ft. in diameter was found. Similar dykes occur, rather more sparsely, along the northern margin of the granodiorite from Lysterfield almost to Aura (Skeats, 1910). A few related dykes have been found in the Upper Dacite north of the granodiorite contact in the railway and road cuttings, and an occasional dyke cuts the metamorphosed sediments near Lysterfield.

The general strike of the dykes in the granodiorite is N-S, with occasional variations to east or west of north, and they have nearly vertical dips. No dykes have been observed in the eastern and southern parts of the granodiorite mass, possibly because outcrops are not favourable. In the north-western section there seems to be an association of dykes with the development of tors, and the majority of the dykes follow a major joint direction in the granodiorite, so that presumably the dykes were intruded after the granodiorite had cooled sufficiently to have developed contraction cracks at its margins.

Felspar-hornblende porphyrites. Felspar-hornblende porphyrite dykes predominate, in which white felspar crystals up to 5 mm. across are set in a dark fine-grained groundmass in which blades of hornblende up to 1 or 2 mm. long may be visible. The felspar phenocrysts consist of strongly zoned crystals of plagioclase, with cores of labradorite and outer shells of acid andesine to oligoclase, recalling the phenocrysts of the Upper Dacite. They tend to be rounded and corroded. They are mostly pellucid, with a tendency for occasional zones to be extensively altered to sericite. Occasional phenocrysts appear to be extensively altered to sericite throughout, but these are probably sections cut parallel to a sericitized zone.

Associated with the plagioclase phenocrysts are prisms and blades of yellow-green hornblende, up to 2 mm. × 1 mm., but mostly smaller, and with random orientation, grading down to fine needles in the groundmass. The groundmass is fine-grained and consists essentially of zoned prismatic to bladed crystals of plagioclase, with lesser amounts of orthoclase and quartz, and fine needles and irregular patches of hornblende.

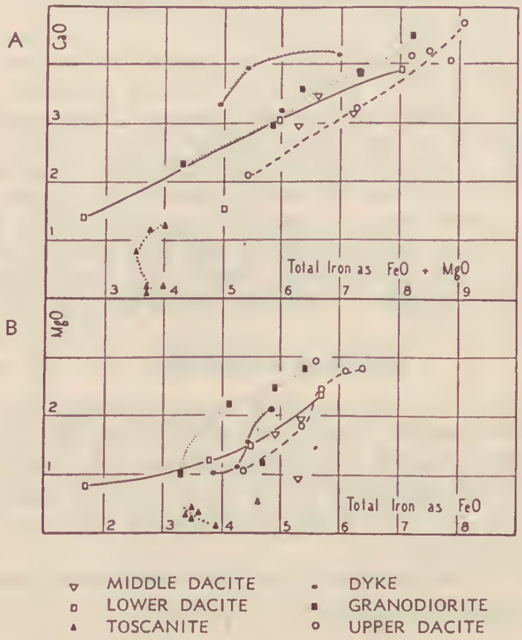

Fig. 5.—A. Varition of CaO in relation to (Total Iron, as FeO, + MgO).
B. Variation of MgO in relation to Total Iron (as FeO).

A chemical analysis of a dyke of this character, striking west of north, and about 1700 yards east of Lysterfield road junction (Ringwood: 346.222) is shown in Table 9, Analysis 34. It is the most basic of the three dykes that have been analysed and bears a close resemblance to the analysis of the felspar hornblende porphyrite dyke cutting through the hypersthene dacite of Ben Cairn, in the Warburton district (Edwards, 1932b). It is distinctly more basic than the porphyrite intrusion in the Middle Dacite north of Kalorama (Table 3, Analysis 13), and is generally similar to the enclosing granodiorite, except that the proportions of the alkalis are reversed, the dyke having the higher potash content.

Porphyrites. A proportion of the dykes is lighter in colour, and less conspicuously porphyritic. They consist of needles of hornblende up to 2 mm. long and white felspar phenocrysts about 1 mm. across, in a light grey groundmass. Thin sections reveal that they consist of few and smaller, but more corroded, phenocrysts of zoned plagioclase set in a more quartz-rich groundmass with abundant granophyric intergrowths of quartz and orthoclase, together with some blocky crystals of zoned plagioclase and scraps of biotite and hornblende. The hornblende phenocrysts are light brown and fringed with minute flakes of biotite. The plagioclase phenocrysts are commonly sericitized. These dykes correspond to the hornblende porphyrites recorded by Skeats (1910) at Aura. Analyses of two of these dykes (Table 9, Analyses 30 and 31) show them to be generally similar to the more acid phases of the granodiorites, but of variable alkali content. Analysis 31 is of dyke 46, which is denser, darker and less conspicuously porphyritic than the more typical dyke 48, the composition of which is given in Analysis 30.

Aplites. A small proportion of the dykes seems best termed aplites, though they still included small corroded phenocrysts of zoned plagioclase. They are predominantly intergrown orthoclase and quartz, some of it granophyric, with patches of fine-grained white mica, and occasional patches of bright green chlorite.

All gradations are present between these three types of dyke rock, from the acid aplitic dykes to the more basic felspar-hornblende porphyrite.

The significance of these dykes is uncertain, but presumably they represent a deeper lying phase of the granodiorite magma, still fluid and only partly crystallized when the upper part of the granodiorite magma had consolidated. Their zoned plagioclase phenocrysts relate them to both the extrusive rocks and the granodiorites.

Chemical Variations

If the chemical analyses of these closely related extrusive and intrusive rocks are plotted in variation diagrams, the diagrams reveal the following:

(i) A series of parallel serial relationships between the analysed specimens of the Lower, Middle and Upper Dacite groups and the granodiorites. For the extrusive rocks the order of the rocks in each series corresponds to their sequence of extrusion.

(ii) That the rocks in the toscanite group are of abnormal composition relative to the other igneous rocks, a fact noted by Morris (1914).

Silica-Alumina Diagrams

In Fig. 3A, CaO content is plotted against combined ($SiO_2 + Al_2O_3$),* after subtracting such CaO as is necessary to satisfy any CO_2 reported in the analysis.

With few exceptions, the points obtained for the dacite groups and the granodiorite fall close to a smooth curve. The CaO in these rocks occurs almost wholly in felspar, and does not enter significantly into the ferromagnesian minerals (except in the hornblende-bearing granodiorites and dyke rocks), so that the curve points to a progressive decrease in the proportions of plagioclase felspars with increasing acidity in all these rocks.

*In rock analyses a common error, not apparent from the totals, is a high Al_2O_3 determination with a correspondingly low SiO_2 determination, arising from the escape of colloidal silica into the R_2O_3 precipitate. The relations shown between the other oxide components of the analyses, and by the general trends of the curves obtained when these oxides are plotted against SiO_2 alone, indicate that this error has occurred to varying degree in several of the analyses available. It can be overcome to some extent by plotting oxides against combined ($SiO_2 + Al_2O_3$).

If separate curves are drawn for each group of closely related rocks, they give for the Lower Dacites, the Upper Dacites and the granodiorites three closely spaced, nearly parallel curves, arranged slightly en echelon, with slightly, and progressively, higher CaO contents for the most acid member of each successively later group—i.e., a slightly higher CaO content for rocks of equal ($SiO_2 + Al_2O_3$) content in each of the successively later groups.

One Lower Dacite analysis (8) falls badly off the curve if corrected fully for its CO_2 content, but would fall close to it if not corrected. The CO_2 content of this analysis is abnormally high for the dacites (1·5 per cent). The comparable curves for FeO and MgO do not show this abnormality, so that it seems likely that the CO_2 content of Analysis 8 has been over-estimated by about 0·7 to 1·0 per cent, or else the CO_2 was introduced after the rock crystallized, and reacted with existing felspars, robbing them of part of their CaO. One Middle Dacite analysis (Analysis 11) also falls off the curve for the same reason. If uncorrected for CO_2 it lies close to the curve.

The toscanite analyses, when allowance is made for their $CaCO_3$ contents, show abnormally low CaO contents, and require that the curve should branch. If no correction is made for CO_2, four of the six points fall close to the normal curve for the dacites and granodiorites.

In Fig. 3B, MgO is plotted against ($SiO_2 + Al_2O_3$). The overall trend for the dacites and granodiorites is a decline in MgO content with increasing acidity. As with CaO, if curves are drawn for the individual groups of rocks a series of more or less parallel curves results, in which there is a slight increase in MgO content for rocks of the same ($SiO_2 + Al_2O_3$) content for each successively younger group.

The toscanites, however, appear as a distinct group with abnormally low MgO contents.

In Fig. 3C, total iron, calculated as FeO, is plotted against ($SiO_2 + Al_2O_3$). The points obtained are more widely distributed than in Figs. 3A and 3B, but if separate curves are drawn for the Lower Dacites, Upper Dacites and granodiorites, a serial arrangement is apparent. One granodiorite analysis (26) and one Middle Dacite analysis (13) appear unduly rich in iron—or possibly in ($SiO_2 + Al_2O_3$). The other Middle Dacite analyses, and the analyses of the dykes, conform to the pattern of the curves.

The curves again show a more or less en echelon arrangement, but their order is different. The Upper Dacites are revealed as richer in total iron than rocks of equivalent ($SiO_2 + Al_2O_3$) content in the other groups. The granodiorites are intermediate between the Lower Dacites and the Upper Dacites for the more acid members, and for the more basic members the granodiorites are the least iron-rich. The Lower Dacite curve steepens for its more basic members, which are as iron-rich as the equivalent Upper Dacites. The Middle Dacites fall on this section of the Lower Dacite curve.

There is here a suggestion that the Upper Dacites and the Middle Dacites derived from an iron-enriched layer in the original magma reservoir, with iron-poorer magma above (Lower Dacites) and below (granodiorites). It may be noted that the Upper Dacites are also somewhat richer in TiO_2 than the rocks of the other groups.

The toscanites again appear abnormal. They are slightly more iron-rich than rocks of equivalent ($SiO_2 + Al_2O_3$) content in the Lower Dacite group, and they show a tendency to become slightly more iron-rich with increasing acidity, the reverse of the trend shown by other groups.

The enrichment of the Upper Dacites in iron, relative to the granodiorites, is confirmed if total iron as FeO, CaO and MgO are each plotted against SiO_2, separately for the Upper Dacites and the granodiorites; and if CaO is plotted against Al_2O_3 for such dacites and granodiorites, throughout Victoria, the dacites show a tendency to be richer in both CaO and Al_2O_3 than the granodiorites (Fig. 4), suggesting an accumulation of plagioclase phenocrysts in the dacites, presumably by sinking of crystals into the deeper, more basic layers of the dacite magma.

Oxide Diagrams

In Fig. 5A, CaO is plotted against combined (Total Iron, as FeO, + MgO), which is equivalent to plotting plagioclase felspar against ferromagnesian minerals. The Middle Dacites and the dyke rocks show an irregular scatter, but the Lower Dacite, Upper Dacite and granodiorite plots fall on three sub-parallel, nearly straight, curves. As in Fig. 3A, one Lower Dacite analysis (8) is distinctly off-line on the CaO-poor side of the curve if corrected for CO_2 content, and is less off-line on the CaO-rich side if not corrected.

The Upper Dacites are revealed as richer in (FeO + MgO) relative to CaO than the other groups, pointing to enrichment of them in iron.

The toscanites appear to be abnormally rich in (FeO + MgO) relative to CaO.

In Fig. 5B, MgO is plotted against total iron (as FeO). Four sub-parallel curves are obtained for the Lower Dacites, Upper Dacites, granodiorites and dyke rocks. One granodiorite analysis (2) falls in the Upper Dacite curve, being abnormally low in MgO, as is one Middle Dacite analysis (13). The other two Middle Dacite analyses fall on the Lower Dacite curve. One Upper Dacite analysis (19) is relatively low in total iron (actually in Fe_2O_3) and falls on the granodiorite curve.

Fig. 5B shows that the ferromagnesians in the Upper Dacites are generally richer in iron relative to magnesium than those in the granodiorites. In the more acid Lower Dacites the ferromagnesians are poorer in iron relative to magnesium than those of the Upper Dacites, but in the more basic members of the two groups they show similar MgO/FeO ratios.

This state of affairs could have been brought about by—

(a) some sinking of early-formed magnesium-rich ferromagnesians into the layer of the magma reservoir represented by the granodiorite, building up the ratio of FeO to MgO in the higher layers; or

(b) some assimilation of sediments rich in iron relative to magnesium in the upper part of the magma reservoir, as discussed later in connection with the toscanites; and

(c) subsequent sinking of the relatively FeO-rich ferromagnesians from the upper layers of the magma reservoir into the layer represented by the Upper Dacites.

The toscanites are again abnormal, having distinctively low MgO contents relative to total iron contents, with a tendency for magnesium to fall as iron increases, the reverse of what is found with the other groups.

In general, Na_2O decreases sympathetically with CaO, corresponding with the occurrence of most of the Na_2O in plagioclase. Potash, as would be expected, varies antipathetically with lime, but the relationship is not well defined, presumably because the potash occurs partly in orthoclase, partly in biotite.

The toscanites again appear somewhat abnormal. With Na_2O, the trend is the reverse of that shown by the other rocks; with K_2O, the trend is different from that shown by the Lower Dacite group, but would fit to an extension of the Upper Dacite and granodiorite curves.

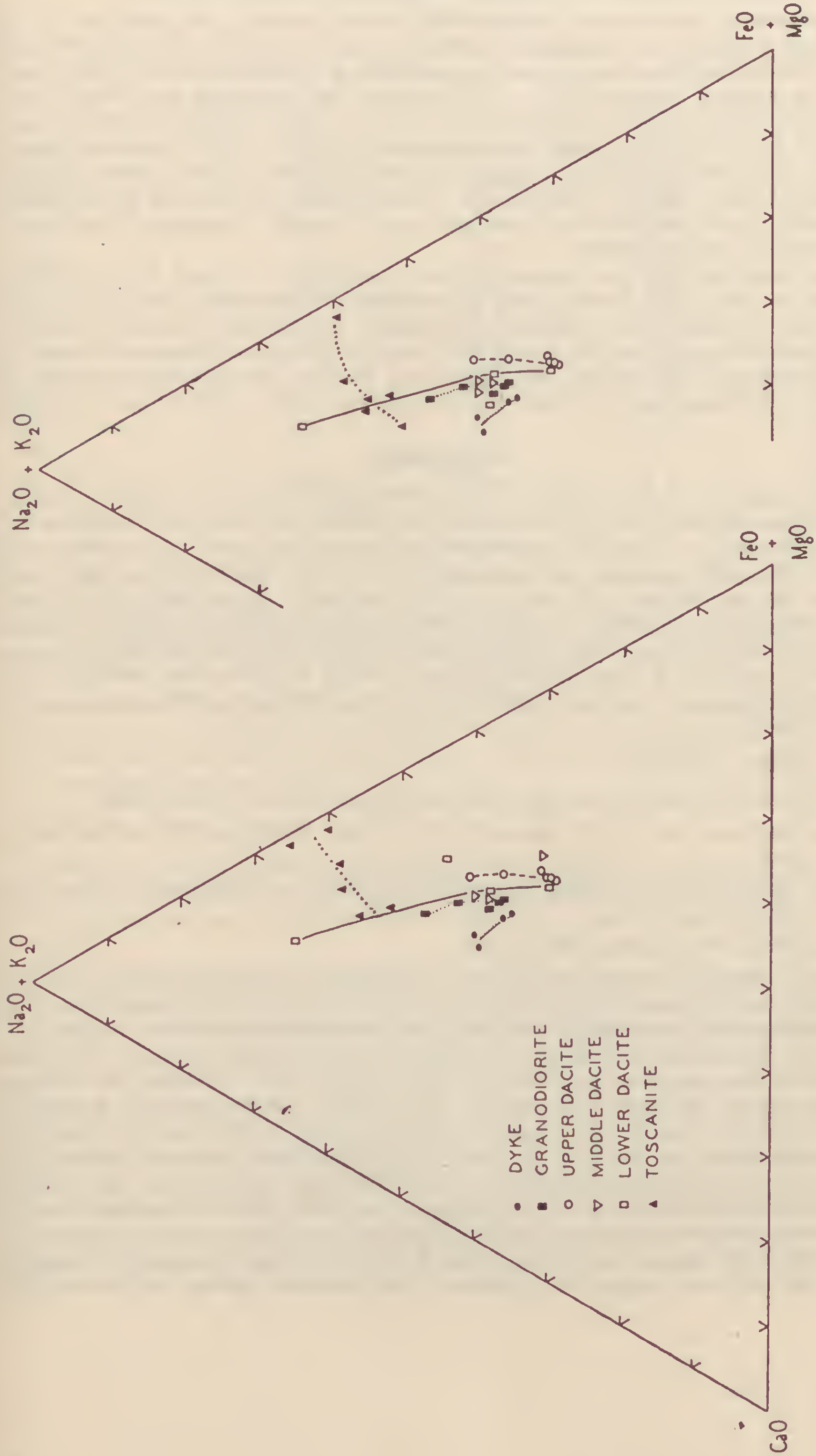

FIG. 6.—Relationship between CaO, total alkalis, and total ferromagnesians (as FeO + MgO). A. Subtracting CaO for CO_2 in analyses. B. Uncorrected for CO_2.

The general relationships between the various oxides in the analyses of the several rock groups are summarized in Fig. 6A. To draw this diagram, the CaO content of the analyses was corrected by subtracting sufficient CaO to combine with any CO_2 reported to form $CaCO_3$. The residual CaO, together with Na_2O, K_2O, MgO and total iron oxides calculated as FeO, were then summed and total alkalis ($Na_2O + K_2O$), CaO, and total ferromagnesians (FeO + MgO) calculated as percentages of this total and plotted against each other as shown. The diagram expresses the parallel trends shown by the Lower Dacites, Upper Dacites and granodiorites, and less clearly by the Middle Dacites and the dyke rocks. It suggests that they all stem from a common magma.

The toscanites follow a separate trend, but appear to branch from the trend followed by the Lower Dacite group. The method of calculating the CaO content emphasises the distinctive trend of the toscanites, but the same trend is apparent if no correction is made, and the total CaO found in the toscanite analyses is used in the summation of the oxides. If this is done, three of the toscanite analyses fall on the Lower Dacite line, one to the left of it and two to the right of it, as in Fig. 6B.

Conclusions

The variation curves of Figs. 3, 5 and 6 indicate that the three groups of dacites, and the granodiorites, have differentiated by parallel processes, presumably from a common magma, to which the hornblende-bearing granodiorite approximates most closely. The differentiation of these groups was not, apparently, a single stage process, but was renewed after each period of extrusion, so that while the differentiation in each stage followed the same trends, it acted on magma of slightly different bulk composition. The Upper Dacites are the differentiation product of magma somewhat enriched in iron, presumably as a result of the earlier sinking out of ferromagnesian minerals from higher level magma during the differentiation of the Lower Dacites.

Origin of the Toscanites

The toscanites differ from the other extrusive rocks in several points:

(a) They are low in CaO, particularly in respect of their ($FeO + Fe_2O_3$) content.

(b) They have a low MgO content, abnormally low in relation to their FeO content.

(c) They are relatively rich in iron.

These differences are not great, but are sufficient to indicate that the toscanites are not normal differentiates of the magma that gave rise to the dacite groups and the granodiorites. Some additional factor has been involved in their origin.

In this connection the chemical composition of a xenolith in the Upper Dacite, near Kalorama, seems significant. It shows (Table 10, Analysis 34) in more extreme degree the features shown by the toscanites; it is extremely deficient in CaO, it is rich in iron oxides (equivalent to 7 per cent FeO), the iron oxides are much in excess of magnesia (1 per cent MgO), and MgO tends to exceed CaO. Its Al_2O_3 content is distinctly greater than that of the lavas, but its SiO_2 content is not greatly different. Table 10 shows, in addition, chemical analyses of two Silurian graywackes and a grey slate, lithologically similar to the Palaeozoic sediments which the igneous rocks have invaded. These analyses show parallel features, but in less extreme degree. It is apparent that extensive mixing of rocks of such

TABLE 10

Analyses of Intruded Sediments

	34	35	36	37
SiO_2	61·38	60·41	74·64	81·60
Al_2O_3	20·28	17·51	12·45	8·64
Fe_2O_3	6·91	2·04	1·92	0·55
FeO	0·78	4·95	3·74	3·08
MgO	0·99	2·93	2·03	1·17
CaO	tr.	0·31	0·08	0·34
Na_2O	1·07	2·77	2·71	1·21
K_2O	3·46	3·92	0·09	1·06
H_2O+	3·38	3·92	0·06	1·30
H_2O-	0·57	0·13	1·28	0·14
CO_2	nil	0·32	0·04	abs.
TiO_2	1·12	0·61	0·79	0·48
P_2O_5	tr.	0·42	0·12	0·24
MnO	tr.	0·10	0·03	0·05
Cl	tr.	tr.	0·02	0·02
SO_3	tr.	0·17	0·01	0·07
Totals	99·94	100·50	100·01	99·96

Explanation

34. Indurated mudstone inclusion in hypersthene dacite, Mount Dandenong. *Analyst*—F. F. Field.
35. Slate, quarry behind (south of) hotel, Warrendyte. *Analyst*—G. C. Carlos.
36. Subgraywacke, north of Doncaster (Ringwood: 174.412). *Analyst*—G. C. Carlos.
37. Subgraywacke, Fritsch Holzer Brickpit, Camberwell. *Analyst*—G. C. Carlos.

composition with magma of the compositions shown by the rhyolites and dacites, and by the granodiorites, could, if combined with normal differentiation processes, have modified the composition of the magma in the directions shown by the toscanites and the hypersthene dacites.

Significance of Hypersthene

In many andesites, diorites and dolerites the tendency is for augite and hypersthene (or their equivalents) to crystallize simultaneously at an early stage, alongside basic plagioclase, and at a later stage in cooling, hornblende takes the place of both pyroxenes.

In the Upper Dacite, by contrast, hypersthene phenocrysts predominate, with practically no augite, and with further cooling the hypersthene, which had become unstable, was replaced by biotite. Where such rocks have been subjected to contact metamorphism, the first effect of heating was to stimulate a reaction between the hypersthene phenocrysts and the orthoclase of the groundmass, to yield biotite. With more intense heating, CaO became available from the plagioclase, and reacted with the biotite to form hornblende, as at Warburton (Edwards, 1932c) and in an undescribed contact of hypersthene dacite with granodiorite in the Macedon district (Parish of Kerrie, allots. 135, 138), discovered by Dr. D. E. Thomas. These contact phenomena establish that it is not lack of CaO in the magma that prevented the formation of augite or hornblende, but its early withdrawal as a stable, "armoured" mineral—namely, strongly zoned lime-rich plagioclase—during or before the crystallization of the ferromagnesians.

Attention has been drawn elsewhere (Edwards and Crawford, 1940, pp. 305-307) to the fact that simultaneous withdrawal of MgO, CaO and Al_2O_3 in the form of basic plagioclase and hypersthene ($\pm$ augite) is a characteristic feature of the differentiation of magmas saturated with SiO_2, which distinguishes them from magmas undersaturated with respect to SiO_2, in which MgO, and to a less extent CaO, are removed independently of Al_2O_3, as olivine and augite, permitting a distinct concentration of Al_2O_3 in the residual magma. The Victorian dacite suite was included in the original comparison.

Normally this behaviour in saturated magmas leads to the simultaneous crystallization of hypersthene and augite. The concentration of the CaO wholly in felspar suggests that at the temperatures prevailing when the plagioclase and hypersthene phenocrysts crystallized, the magma was also saturated, or even over-saturated, with Al_2O_3, so that all available CaO necessarily combined with Al_2O_3 to form plagioclase, in this way accommodating the maximum amount of Al_2O_3 that could be accommodated at these temperatures, but leaving no CaO to form augite (Edwards, 1937, p. 107).

With the slower cooling that prevailed in the granodiorites at subsequent stages of crystallization, any pyroxene became unstable, and the CaO was in part returned to the magma, permitting the formation of some hornblende. With the hypersthene dacites, however, as a result of extrusion, subsequent reaction was limited in range to the "groundmass" in the immediate vicinity of the phenocrysts. As this was predominantly potassic, biotite formed directly at the expense of the hypersthene, and not hornblende (Edwards, 1932a).

Comparison of analyses of hypersthene dacites and related granodiorites from various localities within the rhyolite-dacite-granodiorite province of Central Victoria reveals that though they have generally similar Al_2O_3/CaO ratios, the hypersthene dacites tend to contain more Al_2O_3 and CaO than the granodiorites (Fig. 4), evidence presumably of crystal sinking of plagioclase into the magma layer that gave rise to the hypersthene dacites.

The likely cause of this saturation of the magma in Al_2O_3 is assimilation of argillaceous sediments, such as seems necessary to explain the abnormal features of the toscanites. These rocks, being rich in Al_2O_3, FeO and, in much less degree, MgO, and poor in CaO, could be expected to have an effect parallel to that reported by Bowen (1923, p. 213-214) and by Read (1931) to result from the addition of alumina-rich material to basaltic magma, namely "an increase in the amount of magnesia in the pyroxene, and of anorthite in the plagioclase."

As suggested previously (Edwards, 1937, p. 108), the presence of pyrogenic garnets in the more acid lavas is evidence that they also were saturated or supersaturated with Al_2O_3, so that the effects of assimilation of the roof rocks are apparent in some degree in the whole suite of lavas.

The Structure of the Dandenong Ranges

Morris (1914, p. 359) concluded that "a large rectangular block, including at least the northern part of the Dandenong mountains, has foundered between . . . two fault planes." Of the postulated faults, the westerly "Montrose Fault" was considered to form a linear junction between the Lower Dacites and the Upper Toscanites for a distance of seven miles along the western flank of the Dandenong Ranges, to a point as far south as the Salvation Army farm at Bayswater, while the easterly "Evelyn Fault" was thought to be an arcuate fault bounding the eastern edge of the igneous rocks, and possibly extending from the Yarra River in the north, through Evelyn, to as far south as Monbulk.

Lilydale Hills Syncline

Re-mapping of the igneous boundaries in the northern part of the area, in the light of increased exposures, reveals that they are normal boundaries of superposition, and confirms Hills's (1941) interpretation of Morris's map (1914, Pl. XXX) as indicating that the general structure of the Lilydale Hills is "that of a broadly open syncline". The flow planes in the toscanites which flank the Lower Dacites on the west, north and east, and the contacts of the lava flows, dip inwards at 10° to 15°, so that the syncline pitches gently to the south.

Western or Montrose Monocline

No evidence has been found of the existence of the "Montrose Fault", as such, along the western flank of the Dandenong Ranges proper. As Hills (1941) has shown, the prominent scarp of the ranges is due to a large NE-SW trending monocline, running obliquely across the synclinal structure of the Lilydale Hills from near the Evelyn State School towards Bayswater. As it is followed to the south-west it appears to swing to an increasingly southerly trend through The Basin and Boronia. Beyond Ferntree Gully it cannot be traced.

The lavas have been warped down on the south-eastern and eastern side of the monocline, and the scarp has formed along that part of the steeply dipping limb of the fold that is composed of resistant lavas (Fig. 7). The N-S strike of the flow planes in the lavas at the southern end of the scarp confirms that the monocline is arcuate in trend.

The more or less lobate protrusions of toscanite from the otherwise generally linear margin of the igneous rocks between Montrose and Boronia appear to be infilled valleys of the pre-extrusion surface, comparable with the toscanite-filled valleys at the northern end of the area. Here, however, the infilled valleys are steeply tilted, so that they are seen in cross-section. Because of the hardness of the toscanites, the valleys now outcrop as hills or ridges, while the softer sediments that formed the interfluves between these former valleys now appear as indentations in the margin of the igneous rocks.

A further measure of the steep south-easterly dips of the rocks along the scarp is given by the V-ing of the Middle Dacite-Upper Dacite contact on the geological map (Fig. 2). The angle of dip indicated is 60° to 70° over much of its length. Two sections through the monocline are shown in Fig. 7.

Eastern Margin

The eastern margin of the Dandenong Ranges consists of a combination of faults and a second large monocline. The Evelyn Fault of Morris (1914) can be traced from about half a mile north of the Evelyn State School, southwards across the Olinda Creek and the north-eastern spur of the Dandenong Ranges, to where it again intersects the Olinda Creek (Fig. 1). This fault marks the junction of the Lower Dacite, the Middle Dacite and the Upper Dacite with the Palaeozoic sediments on the east, between these points. The Upper Dacite at the faulted contact is not the dark chilled base of this lava flow, but a relatively light-coloured phase, typcial of its higher levels. The extrusive rocks have been thrown down to the west. The course of the fault is about N-S, and the fault plane dips at about 70° W.

The fault is contemporaneous with the extrusion of the Upper Dacite, since the consanguineous granodiorite that has intruded the Palaeozoic sediments enclosed in the great bend of the Olinda Creek, and in the vicinity of Silvan Dam, has also metamorphosed the Upper Dacite along the faulted contact.

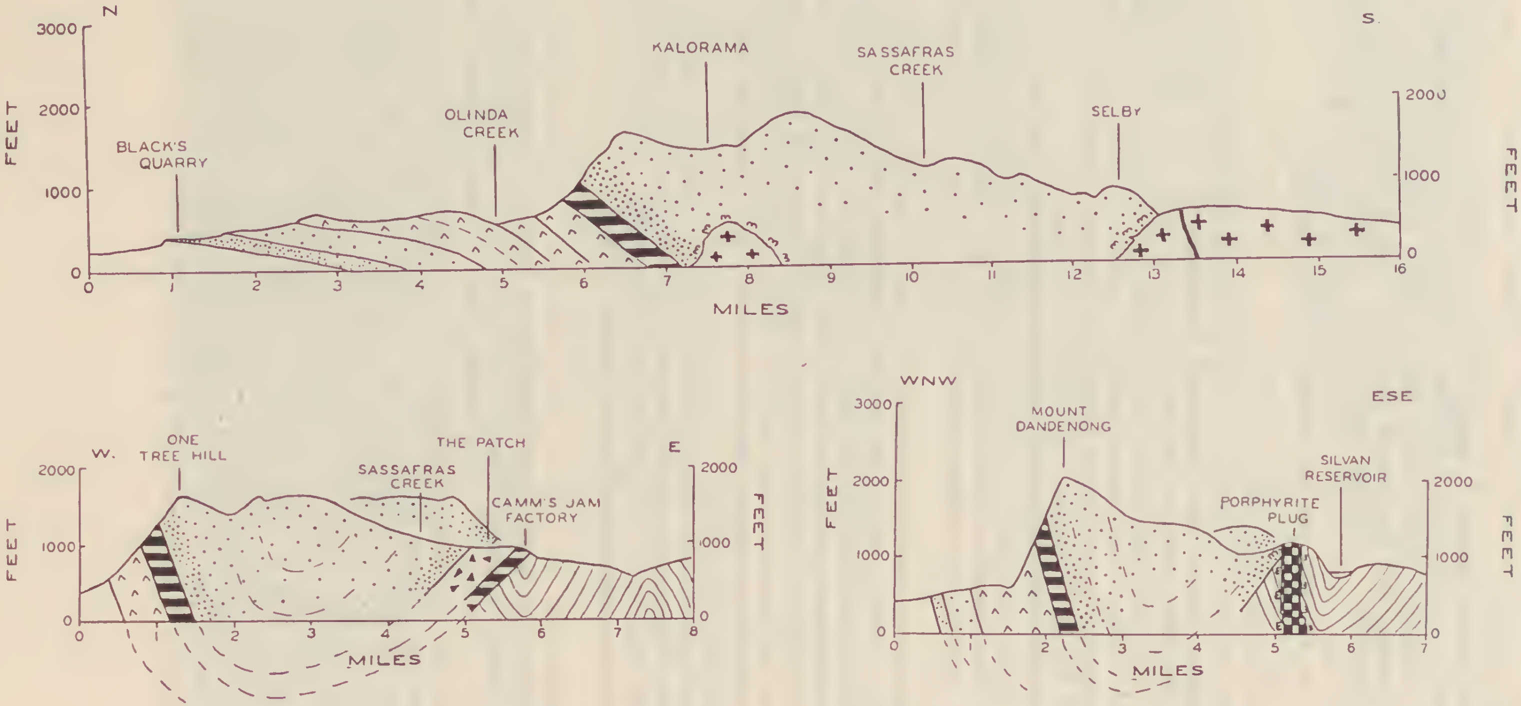

Fig. 7.—Cross-sections through the Dandenong Ranges. (Legend as for Fig. 2.)

The E-W section of the Olinda Creek, upstream from the junction of the Lyre Bird Creek, appears to mark a second fault, striking E-W, along which the dacites appear to have been offset. This also is presumably pre-granodiorite.

Southwards from this section of Olinda Creek the eastern margin of the Dandenong Ranges appears to lie in a monoclinal structure—the Monbulk Monocline (Fig. 1). The margin of the extrusive rocks is marked by steep slopes that die away as they approach the strong ridge separating Lyre Bird Creek from the catchment of the Silvan Reservoir. Along the Silvan Reservoir boundary fence, which follows the crest of this ridge as far as the Chalet-Burleigh road from Olinda, the typical chilled base of the Upper Dacite is found at its contact with the Silurian sediments, and also at its contact with a lobate outcrop of intrusive porphyrite. The chilled base of the Upper Dacite is also found near its rather indeterminate contact with the Palaeozoic sediments on the road from the Chalet guest-house to Burleigh, at the southern end of the reservoir, and on the road from Olinda to Monbulk via Nathania Springs.

From the Chalet-Burleigh road south to about Emerald the margin of the extrusive rocks has a generally linear trend to the south-east. Along most of this stretch it is marked by a scarp similar to that along the western margin of the ranges, but not as high or as steep, and deeply covered with soil and hill-wash. There is a deep embayment in this scarp at The Patch, where the Sassafras Creek issues from the ranges. The embayment has resulted from the "retreat" of the edge of the Upper Dacite up the valley of Sassafras Creek, exposing the underlying pyroclastics and Middle Dacite of The Patch. The contact of the Upper Dacite with the pyroclastics is masked, but the pyroclastics and the Middle Dacite flow outcropping at Camm's Jam Factory appear to dip at about 45° SW (Fig. 7).

South-east of The Patch, where the road from The Patch to Menzies Creek forks at the head of Tea Tree Creek, pyroclastics containing fragments of rhyolite and toscanite dip at 65° to 70° SW, so that they presumably underlie the Upper Dacite of John's Hill, but the broad concave slope of soil and hill-wash between the pyroclastics and outcrops of Upper Dacite masks their full extent and exact relations.

The V-ing of the chilled base of the Upper Dacite where it crosses valleys and ridges, and its generally linear trend, when taken in conjunction with these dips, indicate that the eastern scarp of the Dandenong Ranges, like the western scarp, marks the limb of a monocline. This eastern monocline—the Monbulk Monocline—dips at 40° to 60° SW (Fig. 1).

The view expressed by Morris (1914), that the lavas occur on a depressed block, is therefore substantially correct, except that the depressed block is bounded in the main by monoclines rather than by faults, and tends to the form of a great syncline, rather than of a graben (Fig. 7).

The Southern Margin

The linear and scarp-like character of the southern margin of the Dandenong Ranges (as defined here) raises the question as to whether this margin also is the product of warping or faulting. As Skeats (1910) has shown, the Upper Dacite has been intruded and metamorphosed by granodiorite along the greater part of this southern margin, but at its western end the Upper Dacite is underlain by Middle Dacite. The Middle Dacite outcrops on the northern slopes of the ridge that forms the southern side of the valley of Monbulk Creek, and dips to the north-east at a moderate angle. It is at a lower elevation than the granodiorite to the east of it, so that any Middle Dacite further to the east would have been destroyed by the granodiorite.

The highest level reached by the granodiorite is about 1000 ft. (R.L.) near Aura. The Upper Dacite to the north of it rises to 1378 ft. along John's Hill, and if this dacite had extended far south of its present limits some metamorphosed outliers of Upper Dacite might be expected in the granodiorite area. No such outliers have been found, however, and all the xenoliths examined appear to be derived from sediments.

The chilled base of the Upper Dacite can be seen where it overlies the Middle Dacite, at its south-western limit, but is not apparent along the granodiorite contact. The Upper Dacite away from the immediate contact zone has the features of rock some 200 to 300 ft. above the chilled base.

The outcrop evidence suggests, therefore, that the Upper Dacite has been warped down, or faulted down, to the north, along its southern margin, before the granodiorite was intruded. Consideration of the E-W sections shown in Fig. 6 indicates that the geometry of such a synclinal subsidence requires a matching down-warp or fault along the southern margin of the structure. This hypothetical down-warp is shown in Fig. 1, where it is termed the Selby Monocline.

Time of the Subsidence

The relationship between the Evelyn Fault, the Upper Dacite and the Silvan Granodiorite establishes that the structure developed after the Upper Dacite was extruded and consolidated, but before the granodiorite was intruded.

The relationship of the Lysterfield Granodiorite to the Upper Dacite supports this interpretation, although, as suggested by Skeats (1910), some contemporaneous movement may have been involved to produce the gneissic dacite zones.

The dips shown by the chilled base of the Upper Dacite along the Montrose and Monbulk Monoclines support the idea that the down-warping post-dated the extrusion of this dacite flow.

Cause of the Down-warping

The subsidence of the lavas post-dates the folding of the Palaeozoic sediments and can scarcely be attributed to orogenic movements. The likely cause of it is a collapse of the roof of the magma chamber consequent on the withdrawal of magma to form the Upper Dacite flow. The Lilydale Hills Syncline may be a component of this subsidence, or the outcome of an earlier and lesser sagging in response to the withdrawal of the Toscanite and Lower Dacite magmas, and the possible weakening or thinning of the roof of the magma chamber by assimilation to the extent necessary to develop the toscanites.

The subsidence of the Dandenong Ranges parallels, though on a much smaller scale, the vast Cerberean cauldron subsidence, with its marginal ring dyke of granodiorite porphyrite, that embraces the rhyolites and dacites of the Marysville Igneous Complex (E. S. Hills, in Thomas, 1947). There, as in the Dandenong Ranges, the lavas were subsequently intruded by granodiorite. It would appear that roof subsidence is a characteristic accompaniment of large-scale extrusion of lava in the Upper Devonian rhyolite-dacite-granodiorite province of Central Victoria.

Conclusions

The phenomena described establish that the rhyolite-dacite-granodiorite association in the Dandenongs igneous complex, as at Macedon, Warburton, The Black's

Spur, Marysville and elsewhere within the 10,000 sq. mile Upper Devonian calc-alkaline province of Central Victoria, is the outcome of the differentiation of a granodiorite magma. The various effusive rocks were formed by a combination of fractional crystallization and gravitational differentiation acting in conjunction with the assimilation of Palaeozoic sediments.

Assimilation on a large scale occurs only where the intrusive process is slow and is spread over a considerable area. The general effect of assimilation is to accelerate or retard the normal differentiation process, in that more or less of a particular mineral crystallizes as a result of it, and either sinks or floats, thereby restoring the overall chemical equilibrium of the magma. This could be regarded as an example of Le Chatelier's principle.

For assimilated rock to alter significantly the course of differentiation, it is necessary that its composition should differ notably from that of the magma, as when granitic magma assimilates limestones or highly calcareous sediments. This can be observed on a micro-scale from a study of xenoliths. Assimilation of mudstones and graywackes of the chemical composition shown in Table 10 will not significantly change the course of differentiation of a granodiorite magma, whereas assimilation of these sediments by an undersaturated olivine basalt magma could render it saturated with respect to SiO_2, and so change completely the course of its subsequent differentiation (Edwards and Crawford, 1940).

The granodiorite magma, at each of its centres of extrusion, has risen up through the sediments filling the Victorian Lower Palaeozoic geosyncline. The thickness of these sediments, which range from Cambrian to Devonian in age, has been estimated at 40,000 ft. (Hills and Thomas, 1954) and they are lithologically very uniform, consisting of shales, slates, mudstones and graywackes (subgraywackes), with very minor calcareous intercalations. They are practically devoid of volcanic material, apart from a series of basalts, basic agglomerates and tuffs, at the base of the geosynclinal pile, in the Lower Cambrian. Their effect on the differentiation of the granodiorite magma, at its different centres of extrusion, should, therefore, have been consistent.

The magma could scarcely have originated by the granitization of these sediments because, though they have been strongly folded, they have not suffered any significant degree of dynamic metamorphism, except in north-eastern Victoria, in an area that lies outside the region under consideration. The magma must, therefore, have come from a deeper level of the crust than the base of the geosyncline, and there must have also been a great and continuing supply of heat from this level to maintain its upward progress.

Meta-basalts are recorded from some of the centres of extrusion (Hills, 1932; Thomas, 1947), raising the question as to whether the granodiorite magma is a primary magma or the product of differentiation of a basaltic magma that has assimilated great quantities of sialic material (Edwards, 1937). The present study yields no further evidence on this point.

The granodiorite magma has risen through the full thickness of the Lower Palaeozoic geosyncline, inducing contact metamorphism, but not disturbing the strata. Its relation to the invaded sediments is everywhere cross-cutting. It is sufficiently full of sedimentary xenoliths to leave little doubt that its rise was by a process that involved the piecemeal sinking of blocks of the roof rocks, accompanied by their recrystallization and ultimate dispersion through the magma, and Hills (1932) has described highly hybrid granitic rocks of this character at Marysville.